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ELEMENTS

OF

CHEMISTRY;

CONTAINING THE

PRINCIPLES OF THE SCIENCE,

BOTH

EXPERIMENTAL AND THEORETICAL.

INTENDED AS A TEXT-BOOK FOR ACADEMIES, HIGH SCHOOLS AND COLLEGES.

BY ALONZO GRAY, A. M.
Teacher of Chemistry and Nat. Hist. in the Teachers' Sem. Andover, Ms.

ILLUSTRATED WITH NUMEROUS ENGRAVINGS.

ANDOVER:
PUBLISHED BY GOULD, NEWMAN & SAXTON,
NEW YORK:
CORNER OF FULTON AND NASSAU STS.
1840.

KD 34976

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PREFACE.

THE compiler of the following work originally designed to prepare a text-book on Chemistry, embracing the principal outlines of his course of lectures on this subject, and adapted particularly to the wants of the pupils who might from time to time come under his instruction. But, as experience has shown that most of the text-books in general use, are either too profound on the one hand for those who are commencing the study, or too superficial on the other (for those who wish to obtain more scientific knowledge of the subject,) he has been induced to change his original plan, and attempt to compile a work which should be better fitted for elementary instruction. How far he has succeeded in this attempt must be left to the decision of others.

It is believed, that greater success would attend the efforts of teachers in this branch of science, if more attention were given to the *principles* of Chemistry, and less to its details. The fundamental principles being thoroughly understood by the student, he is prepared to attend to the *details* with greater pleasure and success, as he will be able to connect the effects with their appropriate causes.

Under the influence of this belief, the author has given a greater prominence to the imponderable agents and the thirteen non-metallic substances, than to other parts of the work. Most of the illustrations and experiments are introduced in this part, so as to present and illustrate the philosophy of chemical combinations, and the general nature of the compounds thus formed; in other words, the causes of chemical changes and the mode of studying them.

By the introduction of numerous experiments and illustrations, the object has been to give to the work a practical character, so that the teacher, with a very simple apparatus and with limited means, may be able to give numerous experimental illustrations to his classes.

In the arrangement of the imponderable agents, the phenomena of common and voltaic electricity, electro-magnetism and magneto-electricity, are classed as effects of one agent, electricity. In the arrangement of the simple substances, each with its combinations with those previously described, is presented to the student, in such order, that but one substance with which he is unacquainted is to be studied at the same time.

The salts occupy a separate chapter, in the arrangement of which Turner's Chemistry is made the basis. In the description of substances, brevity has been studied as much as was consistent, often employing the methods used in Natural History. Many subjects of minor importance are only alluded to, and reference frequently made to larger works.

Organic chemistry has become so far a distinct and extensive branch, that a short chapter only was thought proper to be inserted, referring the student to Thompson's Organic Bodies.

The Table of Contents is intended for the purpose of reviewing, instead of questions. The topics are so arranged that the teacher need only mention the subject, and the pupil will thus be able to give a complete analysis of it.

The materials of the work have been compiled principally from Turner's Elements, the works of Henry, Silliman and Webster, and from Griffin's Chemical Recreations.

The author would here acknowledge his obligations to Professor Charles B. Adams of Middlebury College, for important aid in the preparation of this work, and especially in the department of Organic Chemistry.

A. G.

Teachers' Sem. Andover,
July, 1840.

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ERRATA.

On page 37, 38, 39, for Farenheit read Fahrenheit.
" 38, ninth line, for 150° read —150°.
" 39, third line, for 39° read —39°.
" 50, first line, for 920 read 950.
" 51, nineteenth line, in some copies, for Wollaston read Watt.
" 65 and 67, margin, for *Ελεκτϱον* read *Ηλεκτϱον*.
" 93, fourth line, for " insert it " read " insert them."
" 95, third paragraph, for "from north to south" read "from south to north."
" 281 and 285, the words " Sec. 3." and " Sec. 4." should have been omitted."

NOTE.

T. refers to Turnor's Chemistry.
W. " Webster's 3d ed.
Far. " Fahrenheit's thermometer.

Eq. and Equiv. Equivalent.
Symb. symbol or formula.

INTRODUCTION.

SCIENCE is classified knowledge. Physical or Natural Science is the knowledge of the material world. The definition of matter embraces two properties, without which we cannot even conceive of its existence. These properties are *extension*, which includes length, breadth, and thickness, and *impenetrability*, or the impossibility that any two portions of matter should occupy the same space. There are other properties, which do not necessarily enter into our conception of matter, but which universally belong to it, such as gravitation, inertia, mobility, etc.

Natural Science consists of three great branches, which are characterized chiefly by peculiar methods of investigation.

I. NATURAL PHILOSOPHY employs the method of *general physics;* that is, it observes, for example, the gravitation of a stone let fall to the ground, and neglecting the other properties of the stone, observes the same property in other bodies, and *generalizes* the phenomena under a law. It is therefore conversant with general laws, but not with all the general laws, for its observation is restricted to the *phenomena of perceptible distance.* By this we mean that it leaves to the chemist all those phenomena, which arise from the action of the invisible atoms of matter upon each other, and attends only to those which belong to bodies of perceptible size. With a few observations and experiments for data, it depends for discovery upon *calculation*, and its character is therefore eminently mathematical. Its object is a knowledge of the laws of motions and forces.

II. CHEMISTRY employs, in part, the method of *general physics*, *and*, in part, the method of *particular physics*. By the latter we mean that its object is, in part, to describe particular bodies or substances, by giving an account of the various properties of each one, before calling the attention to another. It invites our attention to the phenomena only of *imperceptible distance.* With some aid from calculation and observation, it depends for discovery chiefly upon *experiment*, and has therefore been called experimental philosophy. Its object is a knowledge of the constitution of substances and of the phenomena attending a change of constitution.

III. NATURAL HISTORY employs the method of *particular physics*, observes the phenomena of *perceptible distance*, and depends for discovery chiefly upon *observation*, with some aid from experiment and calculation. Its object is a knowledge of natural objects. It embraces Zoology, or the study of animals, Botany, or the study of plants, Mineralogy, which treats of minerals, and Geology, which describes and accounts for the condition of the crust of the earth. The physiology of plants and animals is sometimes referred to Botany and Zoology respectively, and sometimes regarded as a fourth distinct branch of Natural Science.

Plan of the work.

I. The constitution and the changes of the constitution of substances are intimately connected with the agency of heat, light, electricity and galvanism, of which the two last mentioned agents are now known to be identical. Whether these agents are themselves substances, or mere properties of matter, is not certainly known. They have no appreciable weight, and are therefore called *imponderable agents.* They will form the subject of the first part.

II. The second part will treat of *chemical affinity.* This is the great agent to which all the phenomena of chemistry are referred. It is distinguished from gravitation by exerting its force between the particles of bodies, and from cohesion by acting only between particles of *different kinds* or in different states of electricity. For example, a block of marble is made up of very small particles, each one of which is similar to the whole; but each of these particles is *composed* of two others, carbonic acid and lime, different from each other, and from marble. When these particles of carbonic acid and lime are brought into close proximity to each other, they assume different electrical states, and combine by the force of *chemical affinity*, and form particles of marble. Cohesion then attaches them to each other as fast as formed, and thus the block is formed. Gravity acts upon it in the mass. The carbonic acid and the lime are called the *component* particles. When these combine, they form the *integrant* particles. Hence Chemistry is defined to be that science the object of which is, to examine the relations which *affinity* establishes between bodies, ascertain with precision the nature and constitution of the compounds it produces, and determine the laws by which its action is regulated.

It is the object of Natural Philosophy to examine the sensible motions and mutual relations of bodies in masses, consequent upon *gravity*.

Chemistry investigates the constitution and qualities of bodies as they stand related to *chemical* affinity.

III. The third part will comprise a description of substances, which will be arranged in two general divisions. The first will embrace the elements and those compound substances which can be formed in the laboratory. These are chemical substances. The second division will embrace natural substances, or animal, vegetable and mineral compounds, which have been formed by natural agencies.

Chemists divide substances into simple and compound. A simple substance is one which has never been separated into two kinds of matter, or which has never been decomposed. There are about fifty-four simple substances. A compound body is one which is composed of two or more simple bodies, of which there are many thousands.

The composition of bodies is ascertained by two methods:

1. By separating the body into its simple elements, which is called *analysis;* and

2. By causing the elements to combine and form the body, which is called *synthesis.*

Chemical substances, under the head of *Inorganic Chemistry*, are arranged in three general divisions.

I. Non-metallic elements, and their primary compounds with each other.

II. Metals, and their primary compounds.

III. Salts, or secondary compounds.

In the arrangement of the simple substances and their primary compounds, the logical order is pursued, that is, after describing one substance, the rest are described with the compounds which they form with those previously described.

The Salts are divided into four orders.

I. Oxy-salts, or those salts the acid or base of which is an *oxidized* substance.

II. Hydro-salts, which includes no salt, the acid or base of which does not contain *hydrogen.*

III. Sulphur-salts, which includes none, of which the electro-positive or electro-negative ingredient is not a *sulphuret.*

IV. Haloid-salts, including none, the electro-positive or negative ingredient of which is not *haloidal*, i. e. analogous in composition to sea salt.

CHEMISTRY.

PART I.

IMPONDERABLE AGENTS.

Chapter I.—Caloric.

The word *heat* has two meanings. It is the sensation which we experience, when we touch a hot body ; or it is the cause of the sensation. In the first sense, it is an effect produced only upon animals. In the latter, it is the cause of a great variety of effects in the mineral, vegetable and animal kingdoms. The word *Caloric* (Lat. *calor*) is used in the latter sense. Where there can be no ambiguity, the word *heat* is often retained in the same sense. Caloric exists in a free or sensible, and in a latent or insensible state.

Sensible Caloric. In this state, Caloric is capable of producing the sensation of heat, and of expanding bodies. It has sometimes been called the caloric of temperature. Temperature expresses the power of exciting the sensation, and is proportioned to the quantity of free caloric. A high temperature is owing to a great quantity, and a low temperature to a small quantity.

Insensible Caloric. In this condition caloric produces no sensation, but exists, often in great quantity, in substances, without affecting their temperature, and appears to be combined with them.

SECT. 1. SENSIBLE CALORIC.

Communication of Sensible Caloric.

The most important property of free caloric is its tendency to an equilibrium, that is, a tendency to escape from hotter to colder bodies, so as to produce in all the same degree of temperature. This communication takes place in two ways, by conduction, and by radiation.

Conduction. By this is meant the passage of caloric through a body, from particle to particle. The property in the body, on which this transmission depends, is called the *conducting power.* If one end of an iron rod be held in the fire, the sensation of heat will soon be experienced at the other extremity, in consequence of the conduction of caloric from particle to particle along the rod. If the rod be of glass, it will be much longer before any heat is felt. Hence *different substances conduct caloric with different degrees of facility.*

If two bodies are in contact, caloric may be conducted from one to the other. The more perfect the contact, other things being equal, the more rapid the conduction. The contact of two solids with each other, or of a solid with a gas, is not so perfect as that of a solid with a liquid, and hence the communication is more rapid in the latter case. When liquids are mixed with liquids, or gases with gases, the contact is still more perfect, and the caloric is more rapidly diffused through the whole.

From the two facts, which have been mentioned, it follows that *the rapidity of conduction from a heated to a cold body depends upon the conducting power of each substance, and the closeness of contact.*

Experiment. Plunge a heated iron into cold water, and again equally heated into mercury. In the latter case it will cool more rapidly. For while the heat is conducted with equal facility in both cases from the interior to the surface, it is taken from the surface more rapidly by the mercury than by the water.

Exp. Plunge into mercury two equal balls, one of iron and the other of marble, heated to the same temperature. The iron ball will cool most rapidly, because the caloric is more freely conducted from its centre to its surface.

Exp. Plunge the iron ball into mercury, and the marble into water. The iron will cool more rapidly, for two reasons; the heat will come to its surface more freely, and be taken off by the mercury more rapidly, iron and mercury being each better conductors than marble, or water.

Of the different forms of matter, solids are better conductors of caloric than liquids, and liquids than gases.

Conducting power of solids. This power varies greatly in different solids.

Exp. Prepare some small cylinders of the same dimensions, but of different materials, and apply to one end of each the same degree of heat. Place upon the other ends bits of phosphorus. The caloric will be conducted along from one extremity of each to the other, and the substance, which conducts most rapidly, will first ignite the phosphorus. According to the experiments of M. Despretz, if the conducting power of

Gold be represented by	1000	Tin	303.9
Silver will be	973	Lead	179.6
Copper	898.2	Marble	23.6
Platinum	331	Porcelain	12.2
Iron	374.3	Fine clay	11.4
Zinc	368		

Metals generally are the best conductors of caloric, while furs and porous substances are the poorest conductors.

The conducting power of stones is next to that of the metals, and crystalline stones are better conductors than the uncrystallized.

The earths generally are bad conductors. Bricks, glass, dry wood, charcoal, conduct less, and feathers, silk, hair, and down, least of all. Among the latter, *the finer the fibre the less its conducting power.* Hence the utility of fine wool and furs in the winter, to prevent the escape of caloric from the body, while, in the summer, we select those substances for our clothing which have a coarser fibre. In this we see the benevolence of God in furnishing those animals, which inhabit the colder regions of the earth, with finer clothing than those which inhabit warm climates. The fur of animals is also finer in winter than in summer.

Snow and ice are poor conductors, and hence by a wise constitution the earth in winter is rarely frozen to any considerable depth. The ice and snow keep it warm by preventing its vital heat from escaping.

The conducting powers of solids are generally in the ratio of their densities; especially of the same substance. Increase of density will increase the conducting power, and vice versa.

Conducting power of liquids. In liquids the conducting power is much less than in solids. So feeble is it, that some, among whom is Count Rumford, have denied its existence. But notwithstanding the slight conducting power of liquids, heat can be diffused through them much more rapidly than through solids. This is effected by a motion among the particles, which brings them successively into contact with the heated surface. If, for example, heat is applied to the bottom of a vessel of water, those particles of water, which are in contact with the bottom, are soon heated, and consequently expanded and made lighter, so that they are forced to rise in order to give place to the heavier cold particles, which fall to the bottom. The latter in turn are heated and give place to others, and thus the process continues until two currents are established, one of heated particles rising to the surface, and the other of colder particles falling to the bottom, (fig. 1.) In this way all the water is soon heated by direct contact with the bottom. But if heat be applied to the top of the vessel, the water at the bottom will remain cold, while that at the top is boiling.

Fig. 1.

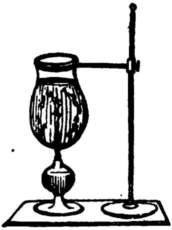
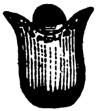
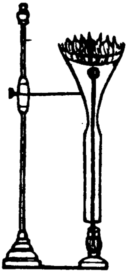


Fig. 2.



Exp. Suspend in a tin cup a hot cannon ball on the top of a jar of water, (fig. 2,) at the bottom of which is a piece of ice. The water will boil rapidly at the top, while the ice remains unmelted.

Fig. 3.



Exp. Or, burn ether (fig. 3.) on the top of a glass funnel filled with water, into which an air thermometer is cemented. The thermometer will not be sensibly affected.

It has, however, been shown that liquids do conduct heat, independently of any intestine motion. But the power is very slight.

Conducting power of gases. Gases and vapors conduct heat very slightly, if at all. Their particles move with so much facility when heated, that it is difficult to arrive at any satisfactory results on this subject. Heat may be diffused through them in the same manner as in liquids, but even more rapidly.

Radiation. If a heated body be suspended in the air, its caloric will be diffused both by the currents of air, which circulate to and from its surface, and, in a slight degree, by the conducting power of the air. But if the hand be placed beneath the heated body, a sensation of heat will be perceived, which is not due to either of these causes, but to the direct passage of the rays through the air. For if a heated body be suspended in a vacuum, entirely removed from conducting substances, it will rapidly cool down to the same temperature with surrounding bodies. Caloric, which is thus thrown off from heated bodies in all directions, like rays of light from the sun, is called *radiant caloric.*

If a thermometer be placed at the distance of two inches from a heated body, it will be affected but one fourth as much as at the distance of one inch; if it be placed at the distance of three inches, one ninth as much; if at four inches, one sixteenth as much; at five inches, one twenty-fifth, etc. Hence, in consequence of a radiation in all directions, *the intensity of the heat is in the inverse ratio of the square of the distance.* The intensity of light and the force of gravitation follow the same law.

The degree of radiation, and consequently the intensity of radiant heat, are greatly modified by the kind of surface. Bright polished surfaces do not radiate so rapidly as those which are dark and rough.

Exp. Take a square tin cup, one side of which is bright, another rough, a third painted black, and the fourth painted white. Fill it with hot water, and bring an air thermometer near each side. The rough and black surfaces will radiate more rapidly than those which are white and polished.*

The greater radiating power of rough surfaces is supposed to be due to the great number of radiating points; or perhaps it may be owing to the greater amount of surface exposed within a given space.

The rapidity of radiation also depends upon the difference between the temperature of the radiating body and that of the surrounding bodies. Hence, with a given temperature of the latter, the higher the temperature of the radiating body, the more rapid the radiation.

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* The late experiments of Melloni do not seem to confirm this view. By using a cup of marble, whose external surfaces were differently prepared, the first polished, the second smooth but tarnished, the third streaked in one direction, and the fourth in two, crossing each other at right angles, and filling the vessel with hot water, each of the sides projected the same quantity of radiant caloric.—*Edin. Philos. Jour. XXVI.* 299.

Radiant caloric passes in right lines through a vacuum, through air and gases without any *apparent obstruction;* but when it falls upon solid or liquid substances, it is disposed of in three ways: 1. It rebounds from the surface or is *reflected.* 2. It enters into the substance, or is *absorbed.* 3. It passes through the body, or is *transmitted.*

Reflection of caloric. When radiant caloric falls upon bright polished surfaces, it is mostly reflected in lines, which form angles with a perpendicular to the reflecting surface, equal to the angles formed by the same perpendicular, and the lines in which the rays went to the surface.

Thus, let BAC (fig. 4,) be a smooth surface, S the incident ray, P the perpendicular to the surface, and R the reflected ray. The angle RAP is equal to the angle PAS. The angle PAS is called the angle of incidence, and PAR the angle of reflection. Light follows the same law. If a concave surface be used, the rays of caloric will be reflected and brought to a focus.—This may be shown by two metallic mirrors, as in fig. 5.

Fig. 4.

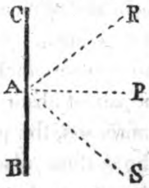
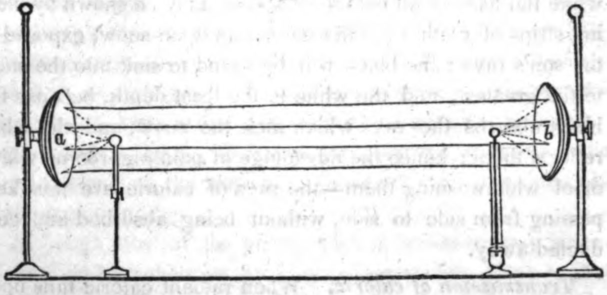


Fig. 5.



a and *b* are two reflectors of polished brass or tin, 12 inches in diameter, and segments of a sphere of 9 inches radius. Place them at any convenient distance apart, from 6 to 12 feet. If a heated ball of iron be placed in the focus *a*, and an air thermometer in that of *b*, the caloric will first radiate to the surface of *a*, and then be reflected in parallel lines to the surface of *b*, when the rays will be reflected to the focus in which the bulb of the thermometer is placed, and will cause the liquid to descend, showing an increase of temperature. If phosphorus be placed in the focus, it will be ignited. If snow be substituted for the heated ball, the thermometer will show, by the rise of the liquid, a diminution of temperature. As bright polished surfaces reflect most of the calorific rays which fall upon them, we can see the reason why they are not easily heated.

Absorption of caloric. When radiant caloric falls upon rough, opaque substances, it is mostly absorbed; that is, it passes directly into the substance and renders it hot; some of the rays are also reflected. The power of absorption, as well as of radiation and reflection, depends mostly upon the surface. Those surfaces which reflect most, radiate and absorb least, and those which radiate and absorb most, reflect least. The power of absorption and of radiation are equal, and as each increases, the power of reflection diminishes. The color of the surface also affects the power of absorption. Dr. Stark has shown that black surfaces, other things being equal, absorb the most; dark green next to black; scarlet next; and white the least of all colors. This fact may be shown by placing strips of cloth of different colors upon snow, exposed to the sun's rays; the black will be found to sink into the snow to the greatest, and the white to the least depth, because the black absorbs the rays which melt the snow, and the white reflects them; hence the advantage of painting rooms white, or of whitewashing them—the rays of caloric are thus kept passing from side to side, without being absorbed and conducted away.

Transmission of caloric. When radiant caloric falls upon the surface of transparent, solid, or liquid bodies, it passes through them in a slight degree. It passes easily through air and other gaseous substances, without sensibly affecting them; but glass and crystalline substances intercept most of the rays. Prof. Leslie contends that glass does not permit the rays to pass directly through it, but absorbs them at one surface, and transmits them to the other by conduction, from which they are again radiated. This opinion is supported by Dr. Brewster by an argument drawn from his optical researches. But the experiments of De la Roche lead to a different conclusion, that the calorific rays do pass through glass, although slowly. This opinion is supported by other chemists.

The radiant caloric which is associated with solar light passes readily through glass and other transparent bodies. The caloric, in this case, seems to be modified by its connection with light, and may be collected into a focus with the light, as in the case of a burning glass. Caloric, thus associated, suffers refraction in passing from one medium to another, and in general is subject to the same laws with light.

Theories of radiation. Of the various theories to account for radiation, only *two* seem worthy of notice. The theory of Pictet supposes that a hot body will radiate caloric to surrounding, colder bodies, until the equilibrium is restored, and then cease. The theory of Prevost supposes that all bodies, whatever be their temperature, are constantly giving out, and receiving radiant caloric. When a body is giving out more rays than it is receiving, it is cooling. When it gives and receives an equal number, its temperature remains stationary, and is in equilibrium with surrounding bodies. When it receives more rays than it gives off, its temperature is increasing. On this theory, all bodies, the polar ice, as well as the burning sands of the tropics, are constantly radiating and absorbing caloric.

Although most of the phenomena of radiation may be explained on both theories, preference is generally given to that of Prevost. The ground of this preference is found in the close analogy between the laws of light and heat, and it is well known that luminous bodies continually exchange rays. A feeble light sends rays to one of greater intensity, and the quantity of rays emitted by each does not seem to be affected by the vicinity of other luminous bodies. In like manner all bodies are supposed continually to exchange rays of caloric.

Application of the theory of Prevost to the explanation of various Phenomena.

1. In the experiments with the mirrors, if the ball in the focus of one mirror is of the same temperature with the thermometer in that of the other, and with surrounding objects, the thermometer will remain stationary, because it receives from the ball the same quantity of rays, which it sends to it; but if the temperature of the ball be raised above that of the surrounding objects, the thermometer will receive more rays than it imparts, and will consequently show an increase of temperature. If ice be substituted for the ball, the thermometer will show a diminution of temperature, because it gives out more rays than it receives.

When ice is placed in the focus of a mirror, *there is an apparent radiation of cold.* But on this theory, it is easily explained; and is what might be expected previous to experiment.* Cold is a negative term, merely expressing the absence, in a greater or less degree, of caloric.

2. *The formation of dew depends upon radiation*, and is satisfactorily accounted for on this theory. The earth, during the day, becomes heated by absorbing the sun's rays, and the moisture is driven off into the air. During the night it radiates more caloric than it receives, and becomes colder than the surrounding atmosphere. Successive strata of air charged with moisture, come in contact with the earth, and the moisture is condensed in the form of dew. The quantity of dew will therefore depend upon the radiating power of the surface, and the quantity of moisture in the air; the more rapid the radiation, the more dew will be formed. There is more dew upon grass and leaves, than upon stones; and the

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* See Turner, 5th edition, p. 13, note.

thermometer will sink 15° or 20° lower, when placed upon grass, than when suspended in the air, or laid on polished surfaces. In India, ice is formed by exposing water in pans in a clear night, when the temperature of the air is never down to the freezing point. But why is there no dew in a cloudy night? Because the clouds reflect back the radiant caloric to the earth, which therefore cannot become cooler than the air. In a clear night, there is no such interchange of rays, and the caloric passes off into the regions of space.

Cooling of bodies. The cooling of a hot body is effected in two ways, already noticed. When surrounded by solid bodies in contact with it, the heat is carried off by conduction, and the velocity of cooling will depend upon the conducting power. When the heated body is immersed in liquids, the same is true to some extent, although much depends upon the mobility of the particles. But when surrounded by gases, the cooling takes place by means of conduction and radiation, and in a vacuum, by radiation alone.

Velocity of cooling means the number of degrees lost in a given time. *Law of cooling* refers to the relation which the velocities of equal successive periods bear to one another. The higher the temperature, other things being equal, the greater the velocity. If a body heated to 1000° lose 100° during the first second, Newton inferred that it would lose $\frac{1}{10}$ of the remainder, or 90°, during the next second, 81° the next, 72.9° the next, and 65.6° the next. These numbers form a geometrical series, whose ratio is 1.111 and though the law is not universal, it holds true, when the temperature is but a little elevated above the air.

Practical application of the laws of conducted, and radiant Caloric. The material for windows should be a bad conductor of heat, as well as transparent; hence glass is best adapted to the purpose. Glass also admits solar heat, while it prevents the escape of artificial heat. Double walls, doors, and windows add to the warmth of buildings, because they confine between them a stratum of air, which, when not in motion, is a good non-conductor. Snow, furs, woollens, etc. are better non-conductors, because they inclose air. Stoves which are rough radiate more heat than those which are polished. As the temperature of the human body usually exceeds that of the atmosphere, the object of clothing in cold weather is to retain the natural warmth, and hence, it is made of good non-conductors. In hot weather, clothing should conduct off the heat more freely. Also, under a hot sun, a black dress is more uncomfortable than one of light color. Many articles employed in the common uses of life are selected with reference to their conducting and radiating properties, as materials for furnaces, culinary apparatus, etc.

Effects of Free Caloric.

The phenomena which may be ascribed to caloric as an agent, and which may therefore be classified, as its effects are numerous; some of these effects will now be enumerated.

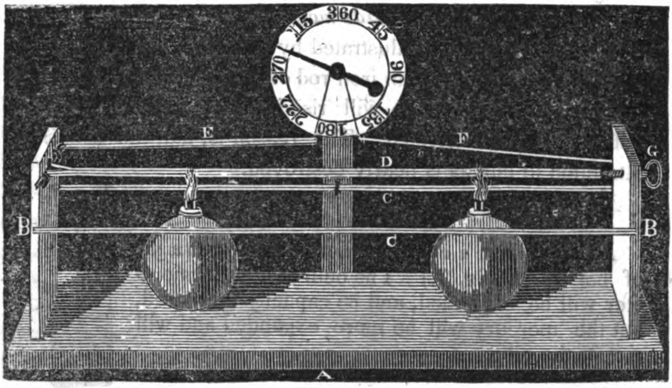
The most remarkable property of caloric, as we have seen is the repulsion, which exists among its particles, by which it tends to an equilibrium, or to bring all substances to the same degree of temperature. This property enables it to penetrate all bodies, and, by its accumulation, to separate the integrant molecules from each other. It thus acts in opposition to cohesive attraction; hence, it may be stated as a general law, *that caloric expands all bodies; liquids* more than solids, and *gases* more than either.

1. *Caloric expands solids.* This may be shown by fitting an iron cylinder to an aperture, so that it will just slide through; heat it, and it will be too large to pass through.

2. *Equal degrees of caloric expand some solids more than others.* This may be shown by an instrument called a pyrometer, or fire measurer. Fig. 6 represents this instrument. It is furnished with several rods, as iron, brass, copper, lead, and glass.

BB, posts standing in A, and secured from spreading apart by the two bars CC. G, a thumbscrew, passing through the post B, and entering one end of the rod D, holds it against a lever at the other end; as the rod is heated, it expands and presses against the lever, which raises E, at the end of which is a cord passing up, over the hub of the index, and down again to the balance rod F; E is raised by the expansion of the rod D, F falls, drawing the cord, and giving motion to the hand.

Fig. 6.



The following substances when heated from 32° to 212° Far. are elongated as follows:

Flint Glass, . .	$\frac{1}{1248}$	of its length,
Iron, . . .	$\frac{1}{812}$	"
Copper, . . .	$\frac{1}{581}$	"
Brass, . . .	$\frac{1}{532}$	"
Lead, . . .	$\frac{1}{351}$	"

3. *Equal Increments, or additions of Caloric, at different Temperatures, do not expand the same solid equally.*

That is, the expansion of a brass, or iron rod will be much greater between 500° and 600°, than between 100° and 200°, or than between 200° and 300°. The higher the temperature, the greater the expansion, with equal additions of caloric. This results from the fact that the power of cohesion is constantly diminished, the farther the integrant particles are removed from each other by heat.

4. *The expansion of some solids is more uniform than others, with equal additions of caloric.* The expansions of the more infusible solids is uniform within certain limits. From 32° to 122°, their expansion is equal to that between 122° and 212°. But above 212°, the higher the temperature, the greater the expansion, for equal additions of caloric.

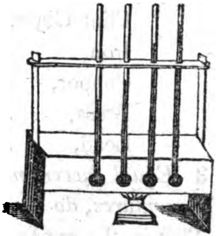
II. *Caloric expands liquids more than solids.*

1. This fact may be illustrated by heating a column of water in a glass tube, and an iron rod of the same dimensions by a spirit lamp; the water will rise in the tube while the iron will scarcely be affected. The reason is, that the cohesive attraction in liquids is nearly destroyed.

Fig. 7.

Exp. Plunge a common thermometer into a jar of hot water, (fig. 7.) The bulb of the thermometer will be expanded, and its capacity increased, but the mercury will be more expanded and will rise in the tube.

Fig. 8.



2. *Equal increments of caloric expand some liquids more than others.* This may be illustrated by partially filling several glass tubes furnished with bulbs, and placing them in hot water; as the liquids expand they will rise to different heights in the tubes; as shown in fig. 8.

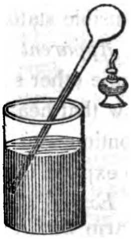
3. *Equal additions of caloric, at different temperatures, do not expand the same liquids equally.* The same law holds here as in the case of solids, the higher the temperature, the greater the expansion for equal amounts of heat; and those

liquids also which expand the least are more uniform within certain limits. Apparent exceptions to the general law are found in the case of some liquids, near the point of congelation. Water expands by a diminution of temperature, and contracts by an addition of caloric, between the freezing point, and 40° Far.

III. *Caloric expands gases more than solids, or liquids.*

1. The expansion of air may be shown by simply inverting a tube terminated by a bulb, and partly filled with water, (fig. 9.) in a vessel of the same liquid; on heating the bulb, the air will expand, and expel the liquid from the tube: or by holding a bladder filled with air near the fire, the air will soon expand, and fill the bladder, and even burst it.*

Fig. 9.



2. *All gases, at any temperature, are expanded equally by equal additions of caloric.* In this respect, gases differ from solids, and liquids. If, therefore, we can ascertain the expansion of one gas for a given number of degrees, we may know that of all others. The law of the expansion of air has been determined by Gay Lussac, who found that a given quantity of dry air, dilates to $\frac{1}{480}$ of the volume it occupied at 32°, for the addition of each degree of Far.

Theory of expansion. This has been already noticed. In the case of solids, the integrant particles are held together by cohesive attraction, but the caloric being self-repellent, has the effect to overcome this force, and to separate the particles from each other.* In case of liquids, cohesive attraction is much more feeble; it will therefore require less power to separate the particles, and hence, they are more expansible than solids. Gases are still less under the influence of cohesion, and hence, are more expansible. In fact, the form which matter assumes, seems to depend upon the relative force of caloric and cohesion. In solids, cohesion preponderates; in gases, caloric; but in perfect liquids these forces are in equilibrium, (the caloric being in a combined, and not a sensible state.)

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* So great is the tendency of air, and other gases to expand, that if a given portion be confined in a bladder, and put under the exhausted receiver of an air pump, the same effect will be produced as when heat is applied; the particles of gases seem to be wholly free from the influence of cohesive attraction, and expand by their own caloric when the pressure is removed.

Apparent exceptions. Allusion was made to water, and some other substances, as apparent exceptions to the general law that heat expands, and cold contracts all bodies. Water continues to contract, until it arrives at 39°, and then begins to expand until congelation takes place.

Exp. Take a glass tube, with a bulb at one end, fill it with warm water, and place it in a mixture of salt and snow. The water in the tube will sink until it arrives at 39° and then begin to rise; the bulk will be increased $\frac{1}{8}$; i. e., if the specific gravity of water be 10, ice will be 9. The maximum density of water is at 39°, Far.

The force of expansion, when water freezes, is very great. The Florentine Academicians burst a hollow brass globe, whose cavity was only one inch in diameter, by freezing the water contained in it. This must have required a force equal to 27,720 pounds. Major Williams, in 1784—5, performed similar experiments at Quebec, by bursting bombs, which also illustrated the amazing force of water in the act of congelation.

In consequence of this expansive force, glass, and earthen vessels are broken, by suffering water to freeze within them;

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* On the supposition that caloric is material, the effect is easily accounted for; but though its particles repel each other, they must have a strong attraction for matter, or they could not be introduced into it. Caloric, therefore, is the antagonist force to cohesive attraction, but possesses a powerful attraction for matter peculiar to itself.

water pipes are burst; pavements are thrown up, and destroyed, and walls, especially in moist grounds, thrown down. The cause of this expansion is supposed to be due to crystallization. The particles, at 39°, seem to be endowed with a kind of polarity, and attract the edges of each other; and, at 32°, they are arranged in ranks and files, which cross at angles of 60°, and 120°, as may be seen when water is freezing in a saucer. This new arrangement of the particles is supposed to increase the bulk, but whether this hypothesis be correct or not, it seems best to explain the effect.*

Advantage of this exception. The wisdom and benevolence of God are strikingly exhibited in this arrangement. Otherwise, all our rivers, and lakes, and the ocean itself, in cold climates, would become solid masses of ice!

When a body of water is freezing, there are two currents established, as in the case of boiling water. The surface gives off its caloric to the air, and the particles become heavy and sink down. This forces the warm particles below to rise. But at 39° these currents are arrested, because the colder particles begin to expand and remain at the top. As soon as they are frozen, a covering of ice prevents in a great measure the escape of caloric from beneath, and the process of freezing is greatly retarded. But if the contraction extended to the freezing point, the colder particles would continue to fall to the bottom, until the whole should be brought to that point, and then suddenly freeze; or if they should freeze upon the surface, the ice would continue to sink down until the whole should become a solid mass.

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* This hypothesis relieves us from the necessity of supposing a real exception to the laws of nature. The effect is due to the operation of another law, (crystallization) to which the law of expansion gives place. For, after the crystallization is completed, the usual law prevails, and ice contracts, with the farther reduction of temperature. Fissures are thus produced in extreme cold weather, by the contraction of ice on ponds.

Hence, in cold climates, the rivers, and lakes would be converted into solid ice, and all their inhabitants be destroyed! But, by this simple and beautiful arrangement, the ice is retained upon the surface, and confines sufficient stores of caloric to preserve the inhabitants of the waters, and render the coldest climates habitable by man.

Water is not the only liquid which expands under the reduction of temperature; as the same effect has been observed in a few others, which assume a highly crystalline structure, on becoming solid. Hence, the exactness with which *cast iron* fills the mould; and the use of *antimony*, in casting types. *Mercury* is a remarkable instance of the reverse, for when it freezes, it suffers a very great contraction.

Practical uses of the general law of expansion and contraction. All kinds of machinery are, of course affected by this law. It must be strictly regarded in the construction of delicate time-pieces. Great use is made of it in the banding of wheels; the iron is heated, and fitted to the dimensions, and then suddenly cooled, so that by its contraction, it presses with great force, and becomes immovably fixed. In riveting together iron plates for steam engine boilers, it is necessary to produce as close a joint as possible. This is effected by using the rivets red hot; the contraction, which the rivet undergoes in cooling, draws the plates together, with a force, which is only limited by the tenacity of the metal of which the rivet itself is made.

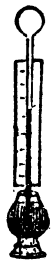
M. Molard, a few years since, at Paris, availed himself of this principle, to restore to their perpendicular direction, two opposite walls of a gallery, which had been pressed outward by incumbent weight. Through holes in the walls, several strong iron bars were introduced, so as to cross the apartment, with the ends projecting; upon which strong iron plates were screwed. The bars were then heated, and while hot, the plates were screwed up. On cooling, the bars contracted, and drew the walls together; by repeating this process several times, they were restored to their original position. Balloons were first sent up filled with air, which had been expanded by heat.

The phenomena of winds depends upon the expansion of the air, by the heat of the sun. In this way the trade winds are produced. Land and sea breezes depend upon radiation, and expansion. During the day, the earth is more heated than the water, and the air is more expanded and rises up. This will produce currents of cold air from the water to the land, called *sea breezes;* during the night, the earth radiates caloric more rapidly than the water, the air becomes cooler, and currents pass from the land to the water, which are called *land-breezes.* Winds are also produced in those deserts which become greatly heated during the day.

Thermometers. But one of the most ingenious and useful applications of this law is to be found in the thermometer. Its invention is generally ascribed to Sanctorius, who flourished in the seventeenth century. Some ascribe it to Cornelius Drebel, and others to Galileo.

Air Thermometers. The substance employed by Sanctorius was atmospheric air, by the expansion and contraction of which he was enabled to measure variations of temperature. His plan was very simple. The instrument consists of a glass tube, (fig. 10.) open at one end, with a ball blown at the other; enough of some colored liquid is poured in to fill half the tube, which is then inverted in a vessel of the same liquid. The air in the bulb, by its expansion, causes the water in the tube to sink, and by its contraction, the pressure of the atmosphere causes it to rise. By adapting a scale to the tube, the instrument was fitted for use.

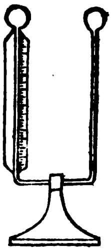
Fig. 10.



On one account air is the best substance for a thermometer, because its expansions and contractions are equal, with equal additions of caloric. But there are two objections to the use of this instrument; it can be depended upon only when the barometer stands at a fixed point; variations of atmospheric pressure materially affect the rise or fall of the liquid. The expansion of gases also, with slight degrees of caloric, is so great, that the length of the tube for measuring high or low temperatures would render the instrument inconvenient in practice.

Differential Thermometer. Sir J. Leslie, in 1804, constructed a thermometer, in which air is used, which is not affected by atmospheric pressure. It consists of two glass balls, (fig. 11,) joined together by a glass tube, bent twice at right angles. The balls contain air, but the tube is nearly filled with sulphuric acid, colored with carmine. To one leg of this tube is applied a scale. It is evident that no effect will be produced upon the liquid, if both balls are heated alike, because the air in both will suffer equal expansion; but the slightest difference between the temperature of the two balls, will instantly be indicated by the rise or fall of the liquid in the tube. Hence its only use is to detect slight variations of temperature between two substances, or of two contiguous spots in the same atmosphere, in very delicate experiments, where caloric is reflected, or refracted to a focus. It is hence called the *Differential Thermometer.*

Fig. 11.



A much more delicate instrument of this kind has been constructed by Dr. Howard of Baltimore, in which the vapor of ether, or alcohol, *in vacuo*, is used instead of air.

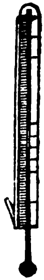
But if air expands *too much*, and is affected by pressure, so as to be unfitted for the common purposes of measuring the degrees of temperature, solid substances, on the other hand, expand *too little.*

The substance most convenient is a liquid, and the object is, to find some liquid whose dilations are nearly equal with equal additions of caloric, and whose boiling and freezing points are removed at the greatest distance from each other. Alcohol and ether would answer this purpose very well in one respect; they resist congelation to a very low temperature, but boil much sooner than water. Mercury seems to be the only substance which will answer the necessary conditions.

Mercurial Thermometer. This instrument is constructed in the following manner. A tube is selected with a small bore, of uniform diameter,—a small ball is blown at one end. The air is then mostly expelled from the bulb, by holding it in a spirit lamp, and the end of the tube quickly inverted in a cup of clear, dry mercury. As the bulb cools, the atmosphere forces the mercury into the bulb, which fills it two thirds full,—the bulb is again heated, and the mercury rises up, nearly filling the tube, and expelling the air. It is again inverted over mercury, when the bulb and one third of the tube are filled; it is then heated until it boils, and fills the tube to the top. A fine flame is then darted from a blow-pipe upon the open extremity of the tube, so as to fuse the glass, and close the aperture before the mercury recedes. It is then said to be *hermetically sealed*, and the space abandoned at the upper extremity of the tube, as it cools, is a vacuum.

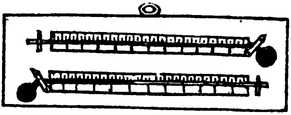
Graduation. This is effected by ascertaining two fixed points, and as water always freezes at the same temperature, and also boils at the same temperature when the barometer stands at the same height; we have only to immerse the bulb and a part of the stem in melting snow, or water containing ice, and mark the point to which the mercury sinks. This is the freezing point. To fix the boiling point distilled water should be used, and the barometer should stand at 30 inches. A small quantity of the water, not more than one inch in depth, and contained in a deep metallic vessel is made to boil briskly, and the point to which the mercury rises, is marked; this is the boiling point. These two points being fixed, the interval is variously divided into equal parts. Newton first suggested a scale, in which the zero was placed at the freezing point, and the interval divided into 40 parts, or degrees. In ***Farenheit's*** *thermometer*, which is generally used in this country and in England, the zero is placed at 32° below the freezing point, and the interval between the freezing and the boiling points is divided into 180 parts, so that the boiling point of water is 212°. Farenheit fixed his zero by immersing the thermometer in a mixture of snow and salt. Reaumur's scale places the freezing point at zero, and the boiling at 80°. Delile placed the boiling point at zero, and the freezing at 150°; this is used in Russia. But the most convenient scale is that of Celsius, in which the freezing point is at zero, and the boiling at 100°, called the *Centigrade thermometer;* this is used in France. The scale is either marked on the tube by a diamond, or on ivory or paper, and attached to the tube. The degrees above the boiling and below the freezing points occupy equal spaces with those between these points. The temperature expressed by one scale can be reduced to that of another, by knowing the relation which exists between their degrees. The lower part of the scale in laboratory thermometers, (fig. 12.) turns up by a hinge, so that the bulb can be immersed in corrosive liquids.

Fig. 12.



Register Thermometer. This instrument consists of two thermometer tubes, (fig. 13.) bent at right angles, and retaining a horizontal position. One tube contains alcohol, and the other, mercury. A small piece of black enamel is placed in the tubes on the surface of each liquid. As the alcohol contracts by exposure to cold, the enamel follows it towards the bulb, but when it expands, the enamel remains stationary, and suffers the liquid to pass by it. When the mercury contracts, the enamel does not follow it; but when the mercury expands, it is forced along. Consequently, it remains at the highest temperature. The enamel, in the tube of alcohol, will in-

Fig. 13.



dicate the lowest, and that in the tube of mercury the highest temperature, during any given time.

For measuring temperatures below 39° Far. the freezing point of mercury, alcohol, or ether must be employed; for temperatures above 662°, no liquid can be employed, as they are all either decomposed, or dissipated in vapors. For very high temperatures, therefore, some of the more infusible solids are used. The instruments for this purpose are called *Pyrometers.* This term is derived from two Greek words, signifying, measurer of fire.

Pyrometer of Wedgwood. This is founded on the property which clay possesses, of contracting when strongly heated, without expanding when cooled; but the indications of this instrument cannot be relied on, and it is seldom used.

Pyrometer of Daniell. This instrument, the best now in use, consists of a bar of platinum enclosed in a case 7½ inches in depth, made of black lead; one end of the bar is fixed, the other is made to move an index, as it is heated. This, however, is not perfectly accurate, owing to the greater expansion of the platinum, in high temperatures, with equal degrees of heat. Generally, these instruments depend upon the elongation of a metallic bar by heat, and one of the best for illustration is described on page 29.

On the same principle, is the *metallic thermometer* of Brequet, for temperatures between the freezing and boiling points of water. It consists of a slip of silver and one of platinum, united face to face with solder, and coiled into a spiral, one end of which is fixed, while the other is connected with an index which moves over a circular, graduated plate. This index is found to move over equal spaces with equal additions of caloric, and so sensible is it to slight variations, that when enclosed in a large receiver, which was rapidly exhausted by an air pump, it indicated a reduction of temperature from 66° to 25° = 41°, while a sensible mercurial thermometer fell only 36°

It will be readily seen, that thermometers do not give us the *absolute*, but only the *relative* quantity of caloric contained in bodies. The true zero, or that point where absolutely no caloric exists, is unknown. Some have conjectured that it is 1200° or 1400° below the freezing point of water. But it is mere conjecture, nor is it known, on the other hand, how high a temperature might result from an accumulation of heat. Neither limit is known. The thermometers and other instruments measure only a few degrees, in the middle of a scale, whose extremities are indefinitely extended.

SECT. 2. INSENSIBLE CALORIC.

Specific Caloric. Every one sees that a quart of water contains double the quantity of caloric, which is contained in in a pint of the same liquid, when the temperature of both is the same. But different quantities of caloric are required to raise equal weights of different substances to the same temperature, and, conversely, different quantities are given out by them in cooling equally. Suppose, for example, that on adding a given quantity of heat to a pound of water at 50°, the temperature will become 60°, the addition of the same quantity to a pound of sperm oil at 50°, will raise the temperature to 70°, while a pound of powdered glass will be raised from 50° to 100° by the same quantity of caloric. The temperature is increased 10°, 20° and 50° in these different substances; i. e. if the required temperature to which they shall be raised be given, the oil will require but half as much heat as the water, and the glass only one fifth as much. *Specific heat is the relative quantity of caloric requisite to raise the temperature of substances equally;* i. e. taking water for a standard at 1, the specific heat of sperm oil will be $\frac{5}{10}$, and of powdered glass $\frac{2}{10}$.*

In these experiments, a portion of caloric disappears. This portion has been called latent or combined caloric, in reference to the theory mentioned in the note below. The phrase *insensible* heat is preferred as not involving any theory.

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* The phrase *capacity for caloric* was formerly used, and was intended to convey the idea, that a portion of the heat enters into and is combined with substances in a latent state; but this is hypothetical, and the phrase specific heat is preferred, as involving merely a fact.

Various methods have been imployed to ascertain the specific heat of substances. The most convenient method is to mix with the substances, all being at the same temperature, a given quantity of some liquid, as water, at some other given temperature, and observe the relative effects. Thus, as in the example given, a pound of water at 80° may be added to a pound of the same at 50°, and the resulting temperature will be the mean 65°; another pound of water at 80° to a pound of oil at 50°, and the resulting temperature will be 70°, i. e. the oil will gain 20° while the water loses but 10°; and again, a pound of water at 80° to a pound of glass at 50°, and the temperature of the mixture will be 75°, the glass gaining 25°, by 5° loss of the water. Other, and more difficult experiments, are necessary to ascertain the specific heat of gases and solid bodies.

The principal laws of specific heat are the following.

1. At the same temperature, and in the case of gases, with the same pressure, the specific heat of each body is constant.

2. The higher the temperature, and in the case of gases, the less the pressure, the greater the specific heat of the same body. This is supposed to be owing to expansion. In gases, the specific heat varies with the density and elasticity; the greater the density, the less the specific caloric; and the greater the elasticity, the greater the specific caloric.

3. A change of form is accompanied by a change of specific caloric. The specific heat of a body, as it passes from a solid to a liquid state, is increased. It is also supposed to be increased by a change of the body from a liquid state to that of a gas or vapor.

4. As each substance has a specific heat peculiar to itself, it follows, that a change of constitution is accompanied by a change of specific heat.

5. A change of specific heat is generally accompanied by a change of temperature. Thus the expansion of a gas, which increases its specific heat, diminishes its temperature.

As a practical inference from the doctrine of specific heat, it may be remarked, that much less fuel will be necessary to heat some substances than others.

Effects of Insensible Caloric.

These are liquefaction and vaporization.*

I. LIQUEFACTION. All bodies exist in one of three states, *solid*, *liquid*, or *gaseous*, and their forms seem to depend, as we have seen (page 32), upon the relative forces of cohesion, and caloric. Hence, by the increase and diminution of either of these forces, we can cause the body to assume either of these states. If a solid be sufficiently heated, it will become liquid, and then gaseous. So general is this fact, that it may be stated as a law.

Point of liquefaction. The temperature, at which liquefaction takes place, is called the *melting point*, or *point of fusion*, as that at which liquids solidify is termed the *point of congelation.* These points are identical; but there is a very great difference in substances as to the degree of heat which is required to fuse them. Each substance has a fixed point of fusion and of congelation.

Caloric of fluidity. If a pound of ice, which is at 32°, be melted in a pound of water at 172°, the temperature of the whole will not be at the mean of 102°, but at 32°, showing that 140° have been taken into a latent state, by the liquefaction of the ice. Generally, liquefaction is accompanied by the conversion of *free* into *insensible* heat. The heat which thus disappears, seems essential to the process of liquefaction, and is called the *caloric of fluidity.* Its quantity varies in different substances, as in the following table.

Ice,	140°,	Far.	Beeswax,	175°,	Far.
Sulphur,	143.68°,	"	Zinc,	490°,	"
Spermaceti,	145°,	"	Tin,	500°,	"
Lead,	162°,	"	Bismuth,	550°,	"

Irvine.

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* Classed as effects of insensible caloric, because the free caloric passes into an insensible state, which is essential to the process.

When the process is reversed, in congelation, this insensible caloric is thrown out in a free state. Thus the freezing of water produces heat.

Freezing mixtures. Liquefaction may be produced without the addition of heat, and hence the caloric of fluidity will be obtained in part, from the temperature of the substances melted, but chiefly from the surrounding bodies; a great degree of cold is thus often produced. On this principle various *freezing mixtures* are contrived. The most common method of producing cold is, to mix together equal quantities of fine salt and fresh fallen snow, or pounded ice. The salt melts the snow by its affinity for water, and the water dissolves the salt so that both are liquefied. The degree of cold produced, is 32° below the freezing point of water, or at zero. This led Farenheit to commence his scale at that point. Any other substance, which has a strong affinity for water, may be substituted for salt. The crystalized *chloride of calcium,* is the best, because it produces the most rapid liquefaction. The following table constructed by Mr. Walker, contains the proportions of several substances to produce different degrees of cold.

MIXTURES.	Parts by weight.	Thermometer sinks	Deg. of Cold produced.
Sea-salt	1	to −5°	
Snow	2		
Sea-salt	2	to −12°	
Muriate of ammonia	1		
Snow	5		
Sea-salt	5	to −25°	
Nitrate of ammonia	5		
Snow	12		
Diluted sulphuric acid	2	from +32° to −23°	55 deg.
Snow	3		
Concentrated muriatic acid	5	from +32° to −27°	59
Snow	8		
Concentrated nitrous acid	4	from +32° to −30°	62
Snow	7		
Chloride of calcium	5	from +32° to −40°	72
Snow	4		
Fused potassa	4	from +32° to −51°	83
Snow	3		

(Freezing may also be effected by the rapid solution of salts.) The following table exhibits the proportions, taken from Walker's essay in the Phil. Trans. 1795. The salts must be finely powdered and dry.

MIXTURES.		Parts by weight.	Thermometer falls	Deg. of Cold produced.
Muriate of ammonia	.	5	from +50° to +10°	40 deg.
Nitrate of potassa	.	5		
Water . .	.	16		
Nitrate of ammonia	.	1	from +50° to + 4°	46
Water . .	.	1		
Nitrate of ammonia	.	1	from +50° to — 7°	57
Carbonate of soda	.	1		
Water . .	.	1		
Sulphate of soda	.	3	from +50° to — 3°	53
Diluted nitrous acid	.	2		
Sulphate of soda	.	6	from +50° to —14°	64
Nitrate of ammonia	.	5		
Diluted nitrous acid	.	4		
Phosphate of soda	.	9	from +50° to —12°	62
Diluted nitrous acid	.	4		
Phosphate of soda	.	9	from +50° to —21°	71
Nitrate of ammonia	.	6		
Diluted nitrous acid	.	4		
Sulphate of soda	.	8	from +50° to 0°	50
Muriatic acid .	.	5		
Sulphate of soda	.	5	from +50° to +3°	47
Diluted sulphuric acid	.	4		

(In order to the greatest effect, the substances should be cooled in a freezing mixture before they are united.) The degree of cold produced by these artificial processes, is limited. The greater the difference between the temperature of the air and that of the mixture, the more rapidly will the air communicate caloric to it, and this soon puts a limit to the degree of cold. According to Mr. Walker, the greatest cold did not exceed 100° below the zero of Farenheit. But a more intense cold is produced by evaporation.

(No process, however, will deprive a body of all its caloric.) Dr. Irvine has attempted to infer the absolute amount from the specific caloric of bodies; thus ice contains $\frac{1}{10}$ less specific caloric than water, and as this $\frac{1}{10}$ is equal to 140°, it is inferred, that water contains ten times the amount, or 1400° of caloric, but the estimates made by different chemists vary from 900° to 8000°, which shows that but little confidence can be put in their calculations.

II. VAPORIZATION. By vaporization is meant the conversion of liquid and solid substances into vapor. It is generally supposed, that if sufficient caloric be applied, all substances are susceptible of this change.

A *gas* differs from a *vapor*, in the circumstance, that it is not so easily condensed into a liquid; it retains its state at ordinary temperatures and pressures. "The only difference between gases and vapors, is the relative forces with which they resist condensation."—T.

Some substances yield vapor readily, and are called *volatile*. Others sustain the strongest heat of furnaces, without volatilizing, and are hence said to be *fixed* in the fire. This difference seems to depend on the relative forces of cohesion and caloric. Liquids are more easily vaporized than solids; and solids, with a few exceptions, like camphor, assume the liquid state before they are converted into vapor.

Liquids may be vaporized in two ways: 1. by ebullition; 2. by evaporation. In the first case, there is a rapid production of vapor, causing commotion in the liquid, and in the second, the process is conducted silently, the vapor imperceptibly passing off from the surface of the liquid.

Ebullition.

Boiling point. The temperature, at which a liquid is converted by ebullition into a vapor, is called its boiling point. This point varies greatly in different liquids, under the same circumstances, and in the same liquid under different degrees of pressure. But each liquid has a fixed boiling point, when all the circumstances are the same.

The chief circumstance, which modifies the boiling point of the same liquid, is the pressure of the atmosphere.

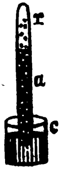
A column of air, extending to the top of the atmosphere, presses upon every square inch of surface with a force equal to 15 lbs. This is sufficient to sustain a column of mercury 30 inches, or a column of water 34 feet. But the pressure varies at different times, on the surface of the earth, and as we ascend high mountains, the pressure diminishes rapidly. The instrument by which this variation is measured is called the *Barometer*.

The principle of which, may be illustrated by filling a glass tube, open at one end, and about 33 inches long, with mercury, and inverting the open end in a cup of the same liquid. The pressure of the atmosphere on the surface, will sustain the mercury in the tube to the height of from 27 to 31 inches.

When the Barometer stands at 30 inches, ether boils at 96°, alcohol at 176°, water at 212°, and mercury at 662°. If the barometer stand at 28, all these substances will boil at a lower temperature, and if it rise to 31 inches, the boiling points will be raised. Hence the two following laws:

1. *As the pressure on the surface of liquids diminishes, their boiling temperatures diminish.* Thus, water heated to 72° and placed under the receiver of an air pump, will boil if the temperature be preserved. Ether will boil violently under an exhausted receiver, at the common temperature of the atmosphere.

Fig 14.



Exp. 1. Fill the barometer tube *a* with mercury (fig. 14.) and invert it in a cup *c* of the same liquid, then introduce a small quantity of ether. As soon as it reaches the vacuum *r* it boils rapidly, and the vapor forces the mercury down the tube.

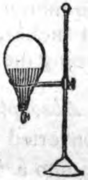
Exp. 2. The pulse glass acts on the same principle, the heat of the hand being sufficient to cause violent ebullition.

Ether boils in vacuo at –44°, alcohol at 36°, and water at 72°, and liquids generally boil at temperatures 140° less *in vacuo* than at the common pressure.

It is owing to this fact, that intense cold can be produced by boiling ether in vacuo. Water, and even mercury, under favorable circumstances, may be frozen. To render the experiment successful, there should be sulphuric acid in the receiver to absorb the vapor of ether, which by its pressure, would otherwise soon prevent the ether from boiling.

2. *As the pressure on the surface of liquids increases, their boiling temperatures increase.* When water is heated to the temperature of 212°, its force upon each square inch is equal to 15 lbs. As this is equal to the pressure of the atmosphere it will, at this temperature, escape in vapor; hence, it cannot be heated in the open air above this point. But if the pressure be increased sufficiently, it may be heated to any extent, without exhibiting the phenomena of ebullition.

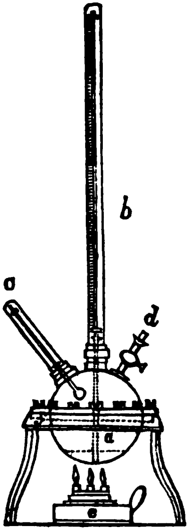
Fig. 15.



Exp. Boil water in a florence flask, (fig. 15.) and cork it tight; the ebullition will instantly cease, because the steam formed will press upon its surface, but by pouring on cold water, and condensing the steam, it will boil violently—pour on warm water, and it will stop boiling. This is a convenient mode of illustrating both of the above laws; as the pressure is increased by the formation of steam, the boiling point is raised, while it is lowered by condensing the vapor and diminishing the pressure. This is called the *culinary paradox.*

But in order to exhibit the influence of pressure upon the boiling point, we must employ a strong metallic boiler, called a *digester*, which consists simply of a strong boiler furnished with stop-cocks and valves, and an apparatus to ascertain the temperature and pressure. Water confined in this boiler may be heated to a very high temperature without boiling, but the steam which will be formed will endanger the boiler, before we can ascertain its greatest expansive force or pressure upon the liquid.

Fig. 16.



For experiments on the pressure of steam, *Marcet's digester* (fig. 16.) is well adapted; *a* is a strong brass globe, into which a portion of mercury is poured, and then half filled with water; *b* a barometer tube passing through a steam tight collar to the bottom of the globe; *c* is a thermometer graduated to 400° or 500°; *d* a stop-cock; *e* a spirit lamp, and *f* a brass stand upon which the whole is supported. Upon the stop-cock *d* a steam gun may be screwed. When heat is applied, the pressure is measured by the height to which the mercury rises in the tube *b*, and the temperature is ascertained at the same time by the thermometer *c*. On the application of heat, as soon as the water boils, the thermometer will stand at 212°, and the pressure, of course, will be equal to one atmosphere, or 15 lbs. to the sq. inch. As the temperature increases to 217°, the pressure will elevate the mercury 5 inches, and at 242° about 30 inches, each degree of temperature raising the mercury about one inch.

Absorption of free caloric in ebullition. When water is converted into steam, a great quantity of sensible heat is taken up into a latent state—which on condensation again appears in a free state. If, for example, steam at 212° sufficient to form one pint of water, be condensed in ten pints of water at 117°, the temperature of the whole will be 212°, the ten pints will be elevated 95°; this is equivalent to raising the temperature of one pint 950°. The latent heat of steam is, therefore 950°; other substances are subject to the same law. Hence, it may be stated generally, that *in ebullition, heat is taken into a latent state, and given out on condensation.*

The latent heat of different vapors is various, as may be seen in the following table:

	Latent heat.
Vapor of water at its boiling point, .	967°
Alcohol, ...	442
Ether, ...	302.379
Petroleum, ...	177.87
Oil of turpentine, ...	177.87
Nitric acid, ...	531.99
Liquid ammonia, ...	837.28
Vinegar, ...	875

Steam is formed, ordinarily, by ebullition. At the moment when water takes the state of vapor, in the open air, it has an expansive force equal to one atmosphere, or 15lbs. on the sq. inch. If then it be disconnected from water, its laws of expansion and contraction, at all temperatures above 212°, are the same as all gaseous bodies. Equal increments of caloric expand it equally, and its expansion is in the ratio of the heating power; for every degree of Farenheit's thermometer, it expands $\frac{1}{480}$ of what its volume would be at 32°, if it did not condense. It may be heated like any gas, until it is red hot, if the vessel is sufficiently strong. But steam is usually formed in the boiler where water is present, and as the temperature increases, fresh portions of steam are constantly added to that which is already formed, so that its expansive force increases in a much more rapid ratio. According to the experiments of Dulong and Arago, if we take atmospheric pressure for a unity, we shall find the pressure of steam at 233.96°, equal to 1½ atmospheres,

250.52	equal to	2	atmospheres, or	30lbs.	to the	sq. inch.
275.18	"	3	"	45	"	"
320.36	"	6	"	90	"	"
374	"	12	"	180	"	"
435.56	"	24	"	360	"	"
486.59	"	40	"	600	"	"
510.60	"	50	"	750	"	"

When steam at a high temperature, is condensed in cold water, a loud crackling noise is heard.

Exp. Let a jet of steam rush from the digestor through a pipe into cold water.

When liquids are converted into vapor, under high pressure, the vapor is very dense. If then, it is allowed to escape from the orifice of the boiler, the hand may be held at a short distance without being burned, though the temperature of the steam, before it escapes, is several hundred degrees. This is due to its expansion, and the consequent absorption of its sensible caloric. When water is converted into steam at 212°, it absorbs 920° of caloric.—If now it be condensed to 32°, it will give out 950° of latent, and 180° of sensible caloric = 1130°. Now, if we take the same weight of steam, at a higher temperature, 250°, and condense it to 32°, it will give out 912° of insensible, and 218° of sensible caloric = 1130°; hence, the *sum of the sensible and insensible caloric contained in equal weights of steam, is exactly the same at all temperatures* = 1130.°

The absorption of caloric seems to perform a similar office in vaporization and liquefaction, being essentially alike to the formation of vapors, and of liquids.

Application of steam to practical purposes.

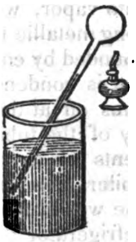
It is used for warming rooms. For this purpose it is conveyed in pipes, and continues to heat the room until its caloric is nearly exhausted. It is then condensed to water, and gives out its latent caloric.

Every cubic foot of steam in the boiler will heat 200 feet of space to 70° or 80°; and each square foot of steam pipe will warm 200 cubic feet of space.

It is used for heating water-baths and dyeing-vats; for bleaching cloth; for producing a vacuum by its condensation; for various culinary purposes; also, for drying various substances, such as muslins, calicoes, gun-power, etc.

But its most important application is to the propelling of machinery; the instrument employed for this purpose is the *steam engine.* The invention of the steam engine is due to Capt. Savery. The principle of his invention may be il-

Fig. 17.

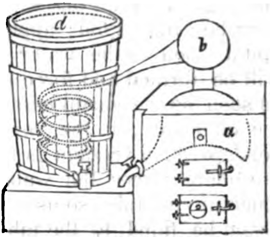


lustrated by a tube, with a ball blown at one end (fig. 17.); fill this with water and invert it in the same liquid; apply heat to the bulb, and as soon as the water is at 212°, steam will be formed and force the water out; but as soon as the steam comes in contact with the cold water in the vessel, it is suddenly condensed; a vacuum is formed, and the atmosphere forces the water with great violence up the tube, so as to fill the bulb. If a piston be fitted to the tube, it will constitute the instrument devised by Dr. Wollaston, except that the steam in his apparatus, is condensed by putting the bulb into cold water. The atmosphere presses the piston down, while it is raised by causing the water in the bulb to boil. The moving power of the steam engine is the same as in this apparatus, but the steam is condensed in a separate vessel called the condenser; this constitutes the improvement of Watt, by which means, the temperature of the cylinder is never below 212° Far.

The steam generator of Mr. Perkins, sustains a pressure of 800, 1000, and even 1500lbs. on the square inch. The steam is then so hot as to set fire to tow, and even ignite the generator at its orifice. At this very high temperature, it is about half as heavy as water. It is a remarkable fact, that at such pressures, the steam will not rush through a small aperture, through which it will rush with great violence, and a roaring noise, when the temperature and pressure are diminished. Mr. Perkins thinks that 400 atmospheres, or 65,000lbs. to the square inch, is the maximum of pressure; i. e. that under this pressure, water will remain liquid at any temperature, even at a white heat. The boiler of the generator is small, and not more than a gallon of water is used at a time.

Steam artillery. Mr. Perkins has succeeded in applying this amazing force to the propelling of cannon balls. He states that sixty 4lb. balls can be discharged in a minute, with the accuracy of a rifle musket, and to a proportional distance. A musket may also be made to throw from one hundred to a thousand balls per minute. It is greatly to be hoped that his experiments will prove successful, for if such engines of death could be brought into the field of battle, few nations would be willing to settle their disputes in that way. Few would fight in the prospect of certain death.

Fig. 18.



Distillation. This process is conducted by converting liquids into vapor, which passes into a long metallic tube, or worm surrounded by cold water. The vapor is condensed, and the liquor runs off at the opposite extremity of the tube. Fig. 18. represents this apparatus ; *a* a copper boiler, *b* its head connected with the worm, which is coiled in the refrigerator *d*, which is nearly filled with cold water to condense the vapor.

Evaporation.

The only difference between evaporation and ebullition is, that the one takes place quietly, and the other with the appearance of boiling. Evaporation takes place at all temperatures, but ebullition at fixed temperatures. The former takes place, not only in all liquids, but in many solids, as camphor ; the latter is confined to liquids.

Evaporation is much more rapid in some liquids than in others, and it is always found that those liquids whose boiling points are lowest evaporate with the greatest rapidity. Thus alcohol, which boils at a lower temperature than water, evaporates also more freely, and ether, whose point of ebullition is yet lower than that of alcohol, evaporates with still greater rapidity. Also, if the temperature of the liquid be raised or lowered, the evaporation will be more or less rapid.

Increase of pressure checks evaporation, and *diminution* of pressure promotes it ; thus water will evaporate much more rapidly in a vacuum. This is precisely what we should expect from the fact just mentioned, that evaporation is most rapid in liquids whose boiling point is lowest, for the diminution of pressure lowers the boiling point. From the three facts which have been mentioned, it may be inferred that (*evaporation is more rapid as the distance between the boiling point and the temperature of the substance diminishes.*)

The other circumstances that influence the process of evaporation are the following:

Extent of surface. As evaporation goes on from the surface, it is evident, that the greater the extent of surface, the more rapid the evaporation.

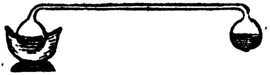
State of the atmosphere. If the atmosphere be already saturated with moisture, evaporation will be checked; or if the air remain still, it will soon become saturated, and the evaporation is promoted by the motion of the air.

Absorption of Free Caloric by Evaporation.

If a dish of water be placed in the exhausted receiver of an air pump, and another, of sulphuric acid, to absorb the vapor of the water, the water will evaporate so rapidly, as to be frozen by the absorption of its sensible caloric.* Hence *the effect of evaporation is to produce cold*—because the sensible caloric passes into an insensible state.

Exp. This may be further illustrated, by filling a small glass tube with water, and surrounding it with cotton wool. If the cotton wool be soaked with ether, and a current of air, from a common bellows, be directed upon it, the water in the course of a few moments, will congeal.

Fig. 19.



Exp. A very satisfactory experiment is performed with the *cryophorus*, an instrument invented by Dr. Wollaston. It consists of two glass balls, (fig. 19.) connected by a glass tube. Both balls are free from air, but one of them contains a portion of distilled water. When the other ball is placed in a freezing mixture, so as to condense the watery vapor as fast as it formed, the evaporation is so rapid from the surface of the water in the other ball, as to freeze it in two or three minutes.

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* The most intense cold which has been produced, is the effect of evaporation. If a large quantity of carbonic acid gas be condensed into a liquid by pressure, and suffered to escape through a small aperture, it will congeal by its own expansion; the solid acid thus formed, will evaporate so rapidly in a vacuum, as to produce the cold of -136° Far. At this temperature, the strongest alcohol becomes viscid, and common alcohol becomes frozen.

Cause of Evaporation. The cause of evaporation is doubtless the same as that of ebullition, *caloric*, although some have attempted to account for it on the supposition of an affinity between the air and the evaporated liquid ; but evaporation in a vacuum is fatal to this hypothesis.

Uses of Evaporation. It is well fitted for cooling apartments. All that is necessary for this purpose, is to sprinkle the floor with water. It moderates the heat of warm climates ; hence places near large bodies of water are cooler in the summer than those more remote, and the greater the heat from the sun's rays, the more rapid the evaporation, and of course the greater quantity of sensible caloric goes into an insensible state.

Evaporation not only takes place from the surface of water, but from the surface of the earth, and from plants and animals ; hence it tends to defend the animal, as well as the vegetable system, from external heat. When an animal is exposed to external heat, perspiration commences over the whole surface, and the liquid, in passing to a vapor, absorbs the sensible caloric. On this principle fire-kings subject themselves to a high temperature, with but little inconvenience. The oven girls of Germany, also, often expose themselves to a temperature of from 250° to 280°, and one girl breathed five minutes in an atmosphere of 325°. In these cases, water boils rapidly, and beef-steak is cooked in a few minutes. If, however, the air be moist, or the body be varnished, so as to prevent perspiration, the heat cannot be sustained for a moment. The heat produced by violent exercise is carried off in the same manner.

But the vital principle, doubtless, has much to do in fortifying the system against the extremes of heat and cold, for though men may be subjected to a range of temperature of more than 400°—from 350° above to 75° or 80° below zero—

the temperature of their bodies does not vary five degrees, but remains stationary at 98° and 100°, during all the varieties of external temperature.

Evaporation often fills the air with deadly miasma. The fever and ague is supposed to be produced in this way. Considerable effect is also produced upon the bulk of gases, and it becomes a point of great interest to ascertain the amount, especially when delicate experiments are to be performed. The atmosphere, of course, always contains a portion of watery vapor. At the freezing point it contains $\frac{1}{480}$ of its volume, and the higher the temperatures, the more vapor is it capable of sustaining. The instruments for measuring the amount of vapor in the air, and other gases, are called

Hygrometers. These vary in form, but may all be reduced to three principles.

The first is founded on the property of some substances to elongate when placed in a moist atmosphere, and to contract when dry. The human hair possesses this property in an eminent degree, and is the substance employed by Saussure.

The second kind of hygrometer depends on the rapidity of evaporation, the temperature and pressure being the same; the more vapor there is in the air, the slower will the process go forward. Leslie's hygrometer is constructed on this principle.

The third kind depends on the fact, that if a cold body be introduced into moist air, the moisture will condense on it; as is sometimes seen on the surface of glass and earthen vessels filled with cold water, and is an indication of rain. The temperature at which the moisture is condensed, is called the *dew point.*

Application of the laws of Insensible Caloric to the explanation of Natural Phenomena.

1. We have seen that when solids are converted into liquids, they absorb large quantities of caloric. Hence the

process of *thawing*, contrary to the common belief, is a *freezing* process. Ice, in becoming water, absorbs 140° of sensible caloric; hence countries surrounded by water are cooler in the spring than those where less ice is formed during the winter.

2. Liquids, in passing to vapors, absorb sensible caloric. In the vaporization of water nearly 1000° of caloric are absorbed. It is therefore a much more powerful cooling process than the liquefaction of ice; hence the heat of warm countries is greatly reduced by the constant formation of vapor. This is the reason why the transition from the cold of winter to the heat of summer is not sudden, but gradual; the ice and the water cannot obtain caloric in sufficient quantities to convert them into vapor.

3. When vapors and gases become liquids, they give out large quantities of caloric; hence it is usually warmer after a rain, a large quantity of caloric being evolved by the condensation of the vapor in the atmosphere.

4. Liquids in becoming solids, give out caloric; hence the process of *feeezing* is a *heating* process. To prevent some substances from freezing, we have only to place them near those which congeal at a higher temperature; thus water placed in a cellar will prevent vegetables from freezing, because they require a lower temperature than water to freeze them; before they reach the point of congelation, the freezing of the water renders its insensible caloric sensible, and prevents them from attaining it.

By the process of converting water into ice, a process constantly going forward when the thermometer stands at 32° Far., large quantities of caloric are thrown off into the atmosphere; hence the shores of a country are warmer in the winter than the interior; hence, too, the approach of the cold season is gradual, the greatest degree of cold rarely occurs till after the winter solstice, twentieth of December. Were these laws suspended, September and March would be of equal temperatures. June would be the warmest, and December the coldest month in the year.

SECT. 3. SOURCES OF CALORIC.

The principle sources of caloric are:

1. The Sun.

2. Chemical action, including electricity, galvanism, and combustion.

3. Condensation by mechanical action, including percussion, and friction.

4. Vital action.

1. *Sun.* The heat produced by the sun varies with the kind, and color of the surface, according to principles already noticed. The temperature produced by their direct action is seldom more than 120°, but when the rays are concentrated by means of convex lenses, or concave mirrors, a very intense heat is produced. Lenses have been constructed concentrating sufficient heat to melt some of the most refractory metals; but the most intense heat, at any considerable distance, is produced by several concave mirrors, which reflect the rays to one focus. Metals and minerals have thus been melted at the distance of 40 feet, and wood ignited at the distance of 120 feet from the mirrors.

2. *Chemical action.* Caloric is often produced by chemical and electrical action. A very great heat occurs in the phenomena of *combustion*, which may be defined to be the disengagement of light and heat in substances by chemical combination. But the most intense heat is produced by voltaic, or electrical action.

3. *Condensation.* It has been already stated, that substances develope caloric by diminution of their bulk, as when gases pass to liquids and to solids. A fire is often kindled by rubbing pieces of dry wood against each other; heavy machinery, if not properly oiled, often ignites wood, and axletrees

of carriages are burned off; the sides of vessels are set on fire by the descent of the cable. The *friction* in these cases condenses the parts, and the caloric is developed. So when iron is struck with a hammer several times, it becomes hot. Fire is also struck from steel with any hard substance like flint. This is denominated *percussion.*

4. *Vital action.* The caloric developed by vital action, is supposed to be owing in part to the chemical action of the air upon the blood, but it is more probable that the vital principle operates to produce most of it, in a way not well understood.

Sources of cold. The sources of cold are, *liquefaction*, *vaporization*, *rarefaction*, and *chemical action.*

SECT. 4. NATURE OF CALORIC.

On this subject there are two theories. Sir H. Davy and some others considered caloric as a property of matter, and Sir William Herschel and Prof. Airy have attempted to explain its nature by supposing that there exists a subtle ether, which pervades all space and all matter, and that caloric is the effect of vibrations made in this fluid, somewhat similar to the vibrations of the air which produce the sensation of sound. This theory is called the *undulatory theory*, and is most favorably received by chemists.

Sir Isaac Newton supposed that caloric was a subtle, material fluid. If caloric is material, it is matter under very peculiar circumstances. So far as we can determine, it possesses few if any of the common properties of matter; its particles are self-repellant, opposed to cohesive attraction. If it is material, its particles must be exceedingly small, as they penetrate all other substances however dense. They must also be influenced by gravity, but no quantity of them, however great, possess the least *appreciable* weight. It possesses neither extension nor impenetrability; but if it is matter, it must have these properties.

CHAPTER II.

LIGHT.

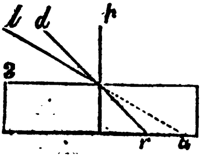
The physical properties of light belong to the science of Optics, a branch of Natural Philosophy. But light has also chemical properties, which come within the province of Chemistry.

Physical properties of light. Light is emitted from every visible point of a luminous object, and is equally distributed on all sides, if not interrupted, diverging like radii drawn from the centre to the circumference of a sphere. It travels at the rate of 192,000 miles in a second, requiring about eight minutes to pass from the sun to our earth. Its velocity is so great, that the light emitted in the firing of a cannon, or a sky-rocket, will be seen by different spectators at the same instant, whatever may be their respective distances from it; the time required for light to travel one hundred or one thousand miles being inappreciable by our senses. When light falls upon any body, it is either *reflected*, *refracted*, or *absorbed*.

Reflection. The reflection of light is influenced by the same circumstances as that of caloric, and follows the same laws; the angles of incidence and reflection are equal. (Fig. 4. page 23.)

Refraction. When a ray passes from a rarer to a denser medium, as from air into water, it is refracted towards a perpendicular to the refracting surface; this property is called *refrangibility.*

Fig. 20.



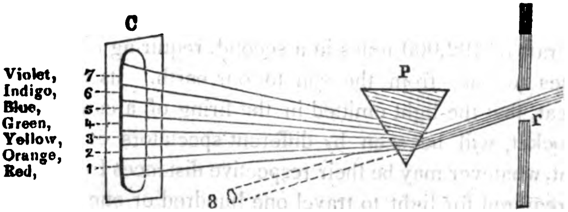
Thus (fig. 20.), *l* is the ray before it reaches the refracting surface 3. Instead of passing directly through to *a*, it is bent towards the perpendicular, to the surface *p*, and proceeds to *r*. But in passing from a denser to a rarer medium, it is refracted from a perpendicular to the refracting surface. Thus, in passing from *r* it is refracted at the surface towards *l* instead of proceeding to *d*. Hence a stick, partly in water, appears bent. Objects viewed through some substances, as Iceland spar, appear double in consequence of a *double refraction.*

Decomposition of light. Solar and stellar light contain three kinds of rays:

1. *Colorific*, or rays of color.
2. *Calorific*, or rays of heat.
3. *Chemical rays*, or those which produce chemical effects.

Colorific rays. These may be separated into seven primary colors: red, orange, yellow, green, blue, indigo and violet.

Fig. 21.



The instrument by which this separation is effected is a triangular prism (fig. 21.) of glass, ice, or any transparent substance. A beam of light *r* is admitted into a dark room, and passing obliquely through two sides of the prism *p*, is refracted by both. The different colors are separated, because some are refracted more than others; and instead of a white spot after the beam passes through the prism, as at 8, there appears a long colored surface *c*, called the *solar spectrum.*

Dr. Wollaston supposes that there are but four colors, viz. red, green, blue and violet, occupying spaces in the proportion of 16, 23, 36, 28.

According to Sir D. Brewster, there are but three colors, red, yellow, and blue, a mixture of which, produces the others.

The prismatic colors differ in their *illuminating power.* This is greatest in the yellow and green, and diminishes each way to the violet and red.

Calorific rays. The calorific rays exist in the greatest intensity in, and near the red rays, and diminish rapidly towards the violet; the greatest heat is sometimes entirely without the red rays; this however depends upon the kind of substances used to separate the rays; in some cases, it is quite on the verge of the orange. *The refrangibility*, then, of the calorific rays is much less than that of the colorific. This is shown also by the fact, that when the solar rays are concentrated by a convex lens, the focus of heat is farther from the lens than that of light.

Chemical rays. On the side of the spectrum, a little beyond the violet, are invisible rays which have a peculiar effect upon chemical changes. They are most powerful on the verge of the violet, and diminish towards the red.

Photographic drawing depends upon the influence of these rays. Exp. Cover glass with beeswax, colored with lamp-black —and draw a picture on it by removing the wax with a sharp point. If then a solution of salt and water be spread on a piece of white paper, and the nitrate of the oxide of silver poured upon it, and placed over the glass, chloride of silver is formed, and the sun's rays will, in a few moments, change the color black wherever they strike this substance.

Exp. Soak a piece of white paper in a saturated solution of bichromate of potassa, dry it rapidly, and put it in a dark room. Place over it prints, dried plants, etc., and expose it to the sun; the objects will be represented yellow on an orange ground. To fix the drawing, wash it carefully to dissolve the salt which has not been acted upon by the light. The object will then appear white on an orange ground.

If sulphate of indigo be used with the bichromate of potassa, it will give to the object and to the paper, different shades of green.

Daguerreotype. A method of fixing the images of objects on metal has lately been devised by Daguerre.

Exp. Expose a plate of silvered copper, well cleaned with dilute nitric acid, to the vapor of iodine; an extremely thin coat of iodide of silver will be formed. Place the plate in the

Camera Obscura for eight or ten minutes; then expose it at an angle of 48° to the vapor of mercury—heat it to 167° Far. and the images will appear. The plate should then be exposed to the action of hyposulphite of soda, and washed in a large quantity of distilled water.*

Magnetic rays. Dr. Morrichini of Rome, discovered that the more refrangible rays, possessed the property of rendering iron magnetic; Mrs. Somerville confirmed this statement by magnetizing a sewing needle with less than two hours' exposure to the violet rays; but others have not been so successful, and it is questionable whether these rays possess this property.

Absorption. The rays of light are separated by *absorption.* When light falls upon a substance, it more or less disappears like insensible caloric.

The different colors are absorbed variously by different surfaces. This is the cause of the great variety of colors, for when all the rays are absorbed except the red, and these only reflected, the body is red. Thus, in colored bodies, only a part of the rays can be reflected, and to the admixture of the different colors in the reflected portion, is owing all the beautiful variety of color.

The absorption of light varies with the chemical constitution; hence by the action of chemical agents upon each other, every variety of color can be produced at pleasure.

Exp. Into a little chloride of calcium, in solution, pour a few drops of sulphuric acid; a white solid will be formed.

Exp. Into a dilute solution of persulphate of iron, pour the tincture of gall; fine black ink will be formed.

Exp. Into an infusion of purple cabbage, put a drop or two of sulphuric acid; a beautiful red will be produced.

Exp. Nitrate of mercury and infusion of gall, will form an orange color.

Exp. Nitrate of lead and hydriodic acid, yellow.

Exp. Vegetable infusion and an alkali, green.

Exp. Aquae ammonia and sulphate of copper, blue.

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* See Jour. Franklin Inst. XXIV. 207.

Exp. Prussiate of potassa and sulphate of iron, indigo.
Exp. Red and indigo mixed, form violet.

When all the rays are absorbed, so that none can be reflected, the body is black; for the same reason, everything is black in total darkness. If none of the rays are absorbed, and all are reflected, the body is white.*

Ignition and Incandescence. The phenomena of ignition and incandescence include all kinds of artificial light, which is obtained by the combinations of inflammable matter, or the heating of non-combustible bodies. Solids begin to emit light in the dark at 700°, and in the light at 1000° Far. Gases require a higher temperature; flame is incandescent gas. The color of the rays depends upon the kind of substances and the degree of heat: the white light of oil, candles, etc., when transmitted through a prism, has but three primary colors, red, yellow and green. The dazzling light emitted by lime intensely heated, gives the prismatic colors almost as bright as the solar spectrum. Different substances assume different colors when intensely heated. Chemical rays exist very feebly in most artificial light, but in the intense light of lime, under the compound blow-pipe, they are more easily detected.

Phosphorescence. There are many substances in nature, which possess the property of *shining in the dark*, without the emission of caloric. These are said to be phosphorescent, and are known by the term phosphori, (although there is no phosphorus connected with the phenomena).

1. *Solar phosphori.* Many bodies acquire this property on exposure to the solar rays for a few hours. Such, for example, is Canton's phosphorus, a composition made by mixing three parts of calcined oyster shells, with one of the flowers of sulphur, and exposing the mixture for an hour to a strong heat in a covered crucible. Chloride of Calcium (Homberg's phosphorus), possesses the same property; also nitrate of lime (Baldwin's phosphorus) and a variety of other substances, such as carbonate of Baryta, Strontia and Lime, the Diamond, Fluor spar or Chlorophane, Apatite, Boracic acid, etc. Scarcely any phosphori act unless they have been exposed to light.

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* **Colors have an important influence on the absorption and disengagement of odorous matters. White bodies are the least absorbent and dark the most so.**

When phosphorescence ceases, it can be restored by a second exposure to the light, or by passing electric discharges through the substance.

Phosphoresence from moderate heat. Chlorophane and several mineral substances require to be heated before they phosphoresce. Lime is a remarkable instance; when heated, it gives out a dazzling white light, too intense to look upon without injury to the eyes.

Animal and vegetable phosphori. Some animal and vegetable substances emit light at common temperatures, without exposure to the sun's rays. This property is remarkable in some fish, as the mackerel; the light makes its appearance just before putrefaction commences, and ceases when it is completely established. Some species of decayed wood possess this property in a remarkable degree.

Light is also emitted during the crystallization of many salts, as the sulphate of potassa and fluoride of sodium.

Exp. Put three drachms of the vitreous arsenous acid into a matrass, with an ounce and a half of hydrochloric acid, and half an ounce of water; boil the mixture for ten minutes, and then suffer it to cool slowly. When crystallization commences, each little crystal will be attended by a spark; on sudden agitation, great numbers of crystals shoot up, accompanied with an equal number of sparks; if larger quantities are taken and the vessel shaken at the right moment, the emission of light is so powerful as to illuminate a dark room.

Photometers. It is sometimes desirable to measure the intensity of light, emitted from different objects, and an instrument has been invented for this purpose called the *Photometer*, or light measurer. The principal one employed for this purpose is that of Leslie.

It consists of a very delicate and small differential thermometer, one bulb of which is made of black glass, and the whole is enclosed in a small glass tube. The white ball transmits all the light and heat, and is of course unaffected; the black ball absorbs all the rays, and heats the air within, so as to cause the liquid to rise. Its action of course depends upon the heat produced by the absorption of light.

Some objections to this instrument have been stated by Turner.

Count Rumford's Photometer determines the comparative strength of lights, by a comparison of the shadows of bodies.

Sources of light. These are similar to those of caloric, the ***sun***, ***stars***, ***chemical action***, ***mechanical action***, and ***caloric***.

Nature of light. Light and caloric have been regarded by some as identical. Newton supposed that light was a material, subtle fluid, which emanated from luminous bodies in all directions in right lines, and produced the sensation of vision, by falling upon the retina of the eye; this is termed the *Newtonian theory*. But Descartes, Huygens and Euler, proposed a different theory, which has been lately revived by Sir John Herschel and Prof. Airy. This theory supposes that light is produced by vibrations in an elastic medium, which pervades all space, and that vision is the effect of these vibrations, meeting the retina, in the same manner as pulsations of air impress the nerve of hearing, and produce the sensation of sound. At present, the strongest evidence is in favor of this theory, which has received the name of the *undulatory theory*. (See Sir J. Herschel's article on Light in the *Encyclopedia Metropolitana.*) Either of the above theories answer the purpose of classifying the facts, and it is not material which is adopted.

CHAPTER III.

ELECTRICITY.

The word *Electricity* is derived from the Greek name for amber,* a substance which possessed the property of attracting light bodies when rubbed.

If a piece of sealing-wax, or a glass rod, be rubbed with a dry woollen, or silk cloth, each becomes capable of attracting and repelling light substances. In this state they are said to be *Electrified*, or *Electrically excited.* When friction is applied to many other substances they exhibit similar phenomena. The cause of this attraction and repulsion is ascribed to an agent called *Electricity*, and when it is excited by friction, it is deisgnated by the title of *Common Electricity.*

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* *Ηλεκτρον.*

If a plate of copper and a plate of zinc, having copper wires soldered to each, be immersed in acidulated water, and the ends of the wires brought into contact, they will exhibit similar phenomena of attraction and repulsion. When electricity is excited in this way, there is always a chemical action between the metal and the liquid, and it is called *Voltaic Electricity*, or *Galvanism*, in honor of Galvani, who made the discovery.

SECT. 1. COMMON ELECTRICITY.

Common Electricity is generally excited by the friction of one substance upon another.

If a piece of sealing wax, or any resinous substance be rubbed with a silk cloth, and a pith ball suspended by a thread be brought near it, the ball will be at first attracted, and then repelled.

If a rod of glass, or other vitreous substance, be rubbed in a similar manner, and brought near the ball, it will attract it, while the sealing wax will repel it. If two balls be each electrified by the sealing-wax, or by the glass, they will repel each other; but if one is electrified by the wax, and the other by the glass, they will attract each other; hence, when friction is applied to resinous, and vitreous bodies, opposite effects are produced. The state induced by friction upon the glass, was called by Dr. Franklin *positive*, and that induced upon the wax *negative*, and the substances were said to be positively or negatively electrified.

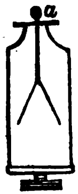
Theories. Franklin supposed that electricity pervaded matter generally, and that friction tended to bring it upon the surface of bodies, or drive it from them.

That it was in its nature self-repellent, but possessed a powerful attraction for common matter; when a body was electrified *positively*, it had more than its share of electricity; when it was electrified *negatively*, it had less than its natural portion.

Du Fay supposed that there was two fluids, the one developed by the friction of the glass, he called *vitreous*, which answers to the positive electricity of Franklin, and the other, developed by the friction of the wax, he called *resinous*, which corresponds with the negative electricity of Franklin. Each fluid repels itself, and attracts the other. It follows from this theory, that *substances electrified by the same fluid repel, and those electrified by the opposite fluids attract each other*, and friction only tends to separate them.

The existence of the two fluids may be shown by the *Gold Leaf Electrometer** (fig. 22.), which consists of two strips of gold leaf suspended by a brass cap and wire, in a glass cylinder. When electrified with either kind of electricity the leaves diverge.

Fig. 22.



But, if when the leaves diverge with negative electricity, a substance excited positively be brought near, the leaves will collapse.

Exp. Bring excited sealing-wax in contact with the brass knob *a*, the leaves will diverge with negative electricity. Place now, excited glass upon the knob, and the leaves will come together, because the positive fluid restores the equilibrium. If pith balls be suspended by a wire or thread, the same effect may be produced.

Some substances, such as glass and resin, retain the electricity upon their surfaces when excited, and are hence called *non-conductors* of electricity.

Other substances, as the metals, do not retain electricity upon their surfaces, unless they are surrounded by non-conductors, but convey it away or oppose no barriers to the union of the two fluids; such bodies are called *conductors* of electricity. The metals are all conductors; dry air, glass, sulphur and resins are non-conductors; water, damp wood, moist air, alcohol and some oils, are *imperfect* conductors. The non-conductors are called *insulators.*

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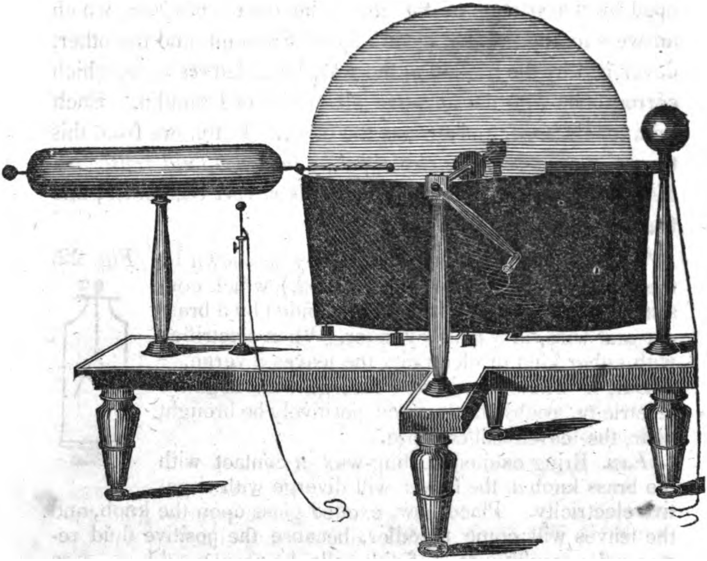
* *Ελεϰτϱον* and *μετϱον*, a measurer of electricity.

Some substances exhibit signs of electricity when heated, such as tourmalin, topaz, diamond, beryl.

Fig. 23.

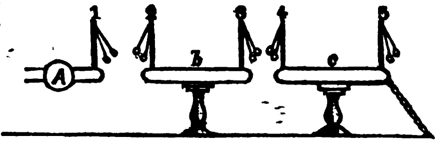


The instrument, by which the phenomena of common electricity may be best exhibited, is the electrical machine (fig. 23), which consists of a cylinder, or plate of glass revolving on an axis, and subjected to the friction of a rubber of leather, or silk, upon which is spread a thin coat of amalgum, composed of tin, mercury and tallow. The rubber is insulated by a glass pillar, and communicates with the ground by a brass chain. Attached to the machine, is a cylindrical metallic conductor, which is also insulated by a glass pillar.

When the machine is in operation, vitreous electricity flows from the rubber and glass, by means of fine points, to the prime conductor, and resinous electricity passes in an opposite direction. If the hand be placed upon the conductor, currents of electricity will pass in opposite directions, the vitreous passing into the body, and the resinous down the chain attached to the rubber to the ground. But if the hand be held at a little distance from the conductor, a spark will dart through the air and cause a prickling sensation, accompanied by a slight report, with light and heat. The sound is produced by the collapse of the air as the fluid forces a passage through it, and the light and heat are supposed to result from the sudden condensation of the air as in the fire syringe.

Induction. If an insulated body be brought near the prime conductor, it will manifest signs of electricity opposite to that of the conductor, on the side nearest the conductor, and similar to the conductor on the other side, while the centre of the body will be neutral. The electricity in this case is induced by the presence of the electrified conductor, and is called *induction.* Several insulated conductors placed contiguous, will exhibit the same phenomena, if a communication be made between the last and the ground.

Fig. 24.



Thus (fig. 24.), let A represent the positive conductor of an electric machine, *b* and *c* insulated conductors with a chain passing to the ground. The conductor *b* will be electrified by induction as will be indicated by the attached balls. Thus, 1 being positive will attract the balls 2, which are rendered negative by induction. The balls 3 are also rendered positive, 4 negative, and 5 positive, while the centres *b c* are neutral.

The phenomena of *induction* led Faraday to propose a theory of attraction and repulsion. The reason why an excited body attracts another is, that it induces in it an opposite electrical state. He considers induction an essential function, both in the development and continuance of electrical currents; that it consists in a polarized state of the particles, or positive and negative points, induced by the presence of an electrified body.

Application of the theory. According to this theory, an excited body attracts light substances, because it induces in them an opposite state of electricity.

On moving the hand towards the prime conductor, it is electrified negatively by induction; when a spark is received the equilibrium is restored.

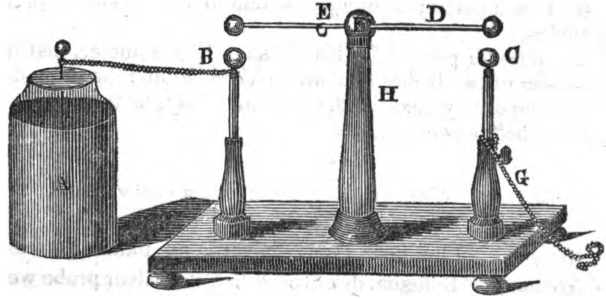
When a cloud, positively or negatively electrified, passes over a tower, or a tree, it induces an opposite state in them, and a stroke of lightning follows in consequence of the attraction between the two accumulated fluids; hence the utility of lightning-rods to form a communication between the clouds and the ground.

The action of the *Leyden Jar* is due to induction. It consists of a glass jar, lined on the inner and outer surfaces, save a few inches near the mouth, with tin foil. Through the stopper, made of dry wood or sealing wax, a brass rod communicates with the inner surface. When positive electricity is applied to the inside, it drives off the same fluid on the outer surface and induces the negative fluid. These fluids exert a strong mutual attraction upon each other, through the glass, and enable both to accumulate in larger quantities than they would do on separate conductors. When a communication is made between the inner and outer surfaces, the equilibrium is suddenly restored, accompanied by a sharp report. When several jars are connected by their outer surfaces, and also by their inner surfaces, they constitute an electrical battery.

The action of the *Electrophorus* (bearer of electricity), depends upon the same principle.

Electrometers, or *Electroscopes.* These are instruments for detecting the presence of electricity, as in the *Gold Leaf Electrometer* (page 67), or for determining the degree of its tension, or attracting and repelling power. For this last purpose, the *Balance Electrometer* is used.

Fig. 25.



Thus A (fig. 25.), is a Leyden Jar, which may be connected with the prime conductor of an electric machine. B an insulated brass ball. C another ball, with a chain. G connecting it with the table on the floor. D a brass rod balanced at the centre F, and insulated by the glass post H. E is a ring which may be placed at any distance from F, bringing the ball in contact with B. If now, the jar be positively electrified, the ball on the end of E will be repelled, C will be electrified negatively by induction, and there will be a powerful attraction between C and the ball on the end of D, which will bring them together, and the equilibrium will be restored. The force of attraction will be measured by the distance between the balls and the weight applied at E. With a powerful battery, successive vibrations may be produced in the beam, and a bright spark emitted at each contact of the balls.

Laws of the accumulation of the Electric Fluid.

1. Free electricity is always accumulated upon the surface of an insulated conductor, and does not penetrate its substance, hence the quantity does not depend upon the *quantity* of matter in the conductor, but upon the *extent* of surface.

2. The mode in which electricity is distributed over the surface of conductors, depends upon their form. On a sphere, it forms a uniform stratum. On an elypsoid, the stratum is thickest on the extremities of the longer axis, and, as these extremities approach to the form of points, the accumulation increases till the tension becomes so great, that it flows off in-

to the atmosphere, hence electricity cannot be retained on a conductor which has points attached to it.

3. This tendency to escape is due to the repulsion of its particles.

4. Coulomb proved by his Torsion Electrometer, that the repulsion of two bodies similarly electrified and the attraction of two oppositely electrified, varies inversely, as the square of the distance between them.

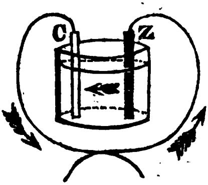
SECT. 2. VOLTAIC ELECTRICITY, OR GALVANISM.

History. In the year 1791, Galvani, an Italian Professor of Anatomy at Bologna, discovered that if a silver probe were made to touch the crural nerve of a recently killed frog, and a strip of zinc the muscle, violent contractions would be produced at each contact of the two metals; the same effect as is produced by an electric spark. Hence he concluded, that the phenomena were due to electricity, generated by the animal system. Some years after, Prof. Volta, of Pavia, discovered that the animal system was not necessary to the development of this kind of electricity, which he proved by the construction of a pile of insulated plates, of different metals, called the *Voltaic pile.* This discovery has given to this form of exciting electricity the epithet *Voltaic.*

But the identity of the agent concerned in Galvanisn, and of that in the common electrical machine, is now a matter of demonstration. *Magnetism* is doubtless due to the same agent, and probably *chemical affinity*, which reduces the four subjects to one, and renders it much more simple, and easy to classify effects which were once supposed to originate from as many distinct agents.

Simple Voltaic circles. Exp. Place a piece of zinc upon the tongue, and a piece of silver under it; whenever the projecting edges of these metals are brought into contact, a peculiar sensation will be perceived, and if the plates are large enough, a flash of light. This effect is not due to the animal system, but to currents of electricity developed in the metals;

Fig. 26.



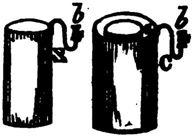
for if the same plates, or larger plates, be placed in water (fig. 26.), and the connection made, electricity will be excited; feeble indeed, but in sufficient quantities to be detected by a proper apparatus. If, however, a few drops of sulphuric or nitric acid be added to the water, and the ends of the plates C and Z brought into contact directly, or by means of wires soldered to the plates, bubbles of hydrogen gas will rise from the surface of the copper plate C, and electricity will be developed in larger quantities. The currents will continue to circulate from one plate to the other, as long as the wires are kept in contact, but will cease when they are separated. This is a case of a *simple Voltaic circle.* The direction of the positive current is indicated by the position of the arrows. When the wires are in contact, the circuit is said to be *closed*, and a current of positive electricity flows through the water from the zinc plate Z, to the copper C, and from the copper along the conducting wires to the zinc. A current of negative electricity, on the theory of two fluids, passes in an opposite direction. When the wires are separated the circuit is said to be *broken.*

The contact may be made above the water, or in it, or the plates may touch each other throughout, or be soldered together; in either case electricity will be excited; but if one plate is out of the liquid, no currents can be produced.

A simple voltaic circle may be formed of one metal and two liquids, provided a stronger chemical action is induced on one side of the plate, than on the other. Simple voltaic circles may also be formed of various materials, but generally, they consist of one perfect and two imperfect conductors of electricity, or two perfect and one imperfect conductors.

Metals and charcoal are perfect; water and aqueous solutions imperfect conductors. But whatever be the construction, *chemical* action seems absolutely necessary to the development of voltaic currents.

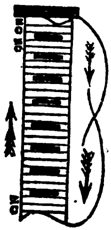
Fig. 27.



The most common and convenient form of the simple battery, is that of two cylinders of copper C (fig. 27.), the one within the other, separated about one inch, with a bottom soldered on, so as to contain the exciting liquid *a* between them, and a cylinder of zinc Z placed between the two cylinders of copper. The two plates are furnished with wires, terminated by the cups *b b*, which contain a globule of mercury. The connection is made by means of wires dipped into the mercury in the cups. Or, the copper and zinc may be coiled around each other, so that each surface of zinc may be opposed to one of copper, but separated from it by a small interval. By thus exposing a large surface of zinc, to a similar surface of copper, Dr. Hare was enabled to melt the most refractory substances, and from this circumstance gave it the name of *Calorimotor.*

Compound Voltaic circles. Compound circles consist of a series of simple circles, for the purpose of increasing the intensity of Voltaic currents. The first combination of this kind was made by *Volta, and is called the Voltaic pile.*

Fig. 28.



This pile consists of zinc and copper plates (fig. 28.) placed alternately one above another, with strips of woollen cloth moistened with salt water between each pair. By connecting the top and bottom plates, currents of electricity will be set in motion.

But other forms of voltaic circles are now in use. The most convenient is that invented by Dr. Hare. It consists of any convenient number of zinc and copper plates, so arranged, that each zinc plate is surrounded by two of copper.

A (fig. 29.) is a mahogany trough to contain the exciting liquid. B a case passing around the plates and connected by chains to the windlass C, by means of which, the plates can be lowered into the liquid, or raised to any position required.* EE are small hand-vices attached to the poles. The zinc plates are confined in copper cases, insulated by wood at each end. The copper cases are separated $\frac{1}{8}$ of an inch by pasteboard, which with the wood is saturated by oil and wax. The connection between the zinc and copper plates is made by strips of copper soldered to the zinc of one pair, and to the copper of the adjacent pair; by this construction, the power of the battery is increased nearly one half.

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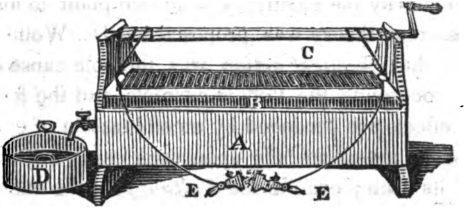
* In some batteries the plates are stationary, and the trough is raised and lowered. This is the most convenient construction, especially in large batteries.

Fig. 29.



As each zinc plate is connected to the adjacent copper plate, the currents are urged along from one to the other, in opposite directions, till they meet at the poles.

The size and number of plates may be varied at pleasure. The largest battery ever constructed, is that of Mr. Children, the plates of which were 6 ft. long, and 2 ft. 8 inches broad. The most convenient size is 4 inches by 6. A battery containing 2 or 300 plates, and thrown into vigorous action, is nearly as powerful as one much larger.* The battery of Dr. Hare, is called a *Deflagrator*, from its surprising power of burning the metals.

The direction of the currents in this apparatus is the same as in the simple circles; positive electricity passes from the zinc through the liquid to the copper plates, and is given off at the copper pole of the battery, while negative electricity takes the opposite direction and appears at the zinc or negative pole.

During the action of the battery, all the hydrogen evolved in the process is given off at the surface of the copper, and the weight of the hydrogen during any given time, and that of the zinc dissolved, will be as 1 to 32.3, which is the ratio of their chemical equivalents. This shows the close connection between electricity thus excited, and chemical affinity.

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* In experimenting with the battery the plates should not be immersed in the liquid but a few minutes at a time; by raising and lowering them for each experiment, their vigorous action will be kept up much longer.

Theories of Galvanism.

On this subject there are three theories. The first originated with Volta, who conceived that electric currents are set in motion, and kept up solely *by contact* of the different metals. He regarded the interposed solution merely as a conductor to convey the electricity from one point to another.

The second theory was proposed by Dr. Wollaston, who supposed that *chemical action* was the sole cause of exciting and continuing the Voltaic currents, and the fact that no sensible effects are produced by a combination of conductors, which do not act chemically upon each other, is the strongest proof of its truth; even in the *Voltaic pile*, the energy of the action depends upon the oxidation of the zinc.

The third theory was suggested by Sir H. Davy, and is intermediate between the two preceding. He supposed that the electric equilibrium was disturbed by *contact* of the metals, and the electric currents kept up by *chemical action*.

The theory of Wollaston is now generally embraced.

Laws of the action of Voltaic circles.

Electricians distinguish between *quantity* and *intensity* in Galvanism, as in ordinary electricity.

Quantity refers to the amount of the electric fluid set in motion. *Tension* or *intensity*, to the energy or effort with which a current is impelled. *Common* electricity has great *tension*. *Voltaic*, great *quantity*, and this is the principal difference between them.

In the broken circuit, there is a strain to establish an electric current, because without this, oxidation cannot take place. There exists between the exciting fluid and the zinc, a desire, as it were, for chemical action, which cannot be gratified until by closing the circuit, a door is opened for the escape and circulation of electricity. This strain or tension is great, according as the affinity between the exciting fluid and the zinc is great. Currents of high *tension* are urged forward with greater impetuosity than feeble ones, and hence they more readily overcome obstacles to their passage.

Currents from a single pair of plates have not a high *tension*, but if the plates are large, a great *quantity* of electricity is set in motion.

The condition which causes a high *tension*, is an extended liquid conductor, along the whole line of which successive pairs of plates are arranged; each acted upon chemically by the exciting liquid, and urging on the current in the same direction. But the quantity in this case may not be great, for although its *tension* is increased by the force which each plate gives to the current as it passes, the *quantity* which passes along the wire, according to Fariday, is exactly equal to that which passes through *one* of the cells in which the plates are immersed.

The *energy* of voltaic currents is measured, either by their power of deflecting a magnetic needle, or by that of *chemical decomposition*. The deflection of the needle depends upon *quantity;* hence a single pair of plates will deflect the needle more than a number of small ones combined, but decomposition depends upon *quantity* and *intensity* together. The decomposing power of the battery, however, does not increase in the ratio of the number of plates, but as the square root of the number, so that when the number varies as 1 to 4, the decomposing power is as 1 to 2.

The deflecting power of a single pair of plates varies inversely as the square root of the distance between them. Thus if a plate of zinc be placed at one, four, and nine inches from a plate of copper, the deflecting powers will be in the ratio of 3, 2, 1.

The velocity of common and voltaic electricity through perfect conductors, is not surpassed by that of light, passing instantaneously through any distance hitherto attempted. Hence this agent has been employed to communicate intelligence from one place to another. *The Electro Magnetic Telegraph*, by which this is effected, depends upon the velocity of electricity and its power to deflect the magnetic needle.

Effects of Galvanism.

The effects of common and Voltaic electricity have many points of resemblance. If a zinc and copper plate be immersed in dilute nitric acid, and the wire attached to the zinc plate be made to touch a gold leaf electrometer, the leaves will diverge with negative *electricity*, and if the wire of the copper plate be applied, it will indicate *positive* electricity. This effect is much greater when a battery of several pairs of plates are employed. It appears to be due to the disturbed equilibrium in the zinc plate,—the chemical relation of which to the acid renders the metal *positive* at the expense of the attached wire, while the copper plate, induced by the contiguous zinc, becomes *negative* at the expense of its wire which becomes positive.

A *Leyden Jar* may be charged from either wire of an unbroken circuit, provided a large quantity of electricity be developed, connected with high *tension*. This effect depends upon the number of plates and the energy of the action.

Voltaic, like common electricity, passes through the air and other non-conductors, in the form of sparks, accompanied with a report, and the development of light and heat. Hence it will inflame gun-powder, phosphorus, hydrogen and oxygen, and other inflammable substances.

Its *tension*, however, is so feeble compared with common electricity, that it has, according to Mr. Children, a very small *striking distance*, i. e. the space of air through which the spark will pass is comparatively small. With a battery of 1250 pairs of four inch plates, he found the striking distance to be $\frac{1}{50}$ of an inch. If the air be rarified, the distance will be increased, and diminished by condensation.

The effects of voltaic electricity upon the animal system is the same as that of common electricity.

Both kinds also deflect the magnetic needle, and produce chemical decomposition.

One of the most surprising effects of voltaic currents *is their power of igniting the metals.*

Exp. Attach to each pole of the battery strips of metallic leaves and bring them in contact, the metals will burn with the most vivid scintillations. (See fig. 29.)

The color of the light varies in different metals. Gold leaf burns with a white light, tinged with blue, and yields a dark brown oxide. Silver emits an emerald green light of great brilliancy. Copper a bluish white light, with red sparks. Lead a beautiful purple, and zinc a brilliant white light, tinged with blue and red. If the communication be made with charcoal points (that from the box-wood is the best), the light is equal, if not superior in intensity, to that emitted during the combustion of phosphorus in oxygen gas, and the heat is sufficient, it is said, to partially fuse the carbon, a substance which is fusible by no other means of producing heat.*

The heating power seems to be due, for the most part, to the *quantity* of electricity developed, hence for melting wires, a *calorimotor* is preferable to a *compound battery*. The heat is supposed to arise from the difficulty with which the electric currents pass along the conductors ; but as the substances are good conductors, the effect will take place only when the quantity of electricity transmitted, is out of proportion to the extent of surface over which it has to pass.

As heat and light are equally well produced *in vacuo*, under water, or in gases which do not contain combustible matter, this phenomena cannot be attributed to *combustion*, but to the production of light and heat by the electric fluid itself.

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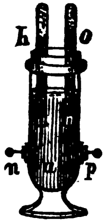
* On examining the points after they have been subjected to the action of a powerful battery, one will present a conical appearance like the head of a pin, the other a corresponding cavity. The matter thus transposed has been supposed to be partially melted, but probably it is nothing but earthy matter in the carbon.

The effects of common electricity from the electric machine, and in the case of lightning, are so similar to those above described, that there can be no doubt of the *identity* of the agents concerned in their production.

Chemical effects of Galvanism. The phenomena which accompany *chemical combinations* are similar to those produced by voltaic electricity. But the agency of voltaic currents to effect the decomposition of chemical compounds is a most important and useful discovery which was first made by Carlisle and Nicholson.

Fig. 30.



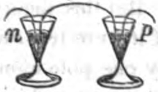
The first substance decomposed by the Galvanic battery was water. The water for decomposition is put into a small vessel *a*, (fig. 30.) The tubes *h o*, after being filled with water, are inverted in the vessel, passing through holes in the stopper; *n* and *p* are platinum wires passing through the sides of the vessel into the open ends of the tubes. When the poles of the battery are connected with the wires, the positive with *p*, and the negative with *n*, hydrogen gas is disengaged at the negative, and oxygen at the positive wire. The two gases will rise up in the tube in small bubbles and displace the water. By measuring the gases, it will be found that there will be exactly two measures of hydrogen in the tube *h*, to one of oxygen in the tube *o*. If the gases are collected in the same tube and exploded in the eudiometer, they will entirely disappear, and water will again be formed. By this means the compoposition of water, both by analysis and synthesis, is accurately ascertained.

This important discovery led to similar trials upon other substances. Other compounds, such as acids, salts and alkalies were subjected to the agency of Galvanism, and all were decomposed—one of their elements appearing at the positive, the other at the negative pole. In these decompositions, it was found that the same kind of body always went to the same pole. The metals, inflammable substances in general, alkalies, earths, and the oxides of the common metals were uniformly found at the negative wire, while oxygen, chlorine

and the acids were found at the positive pole. This led to a division of substances into *Electro-positive*, and *Electro-negative*, a distinction, however, which is not found by later experiments, to accord with facts.

The *transfer* of chemical substances from one vessel to another was noticed by Sir H. Davy. This transfer may be shown by two wine glasses, (fig. 31.)

Fig. 31.



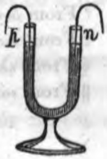
Put a solution of sulphate of soda into one *n*, and distilled water into the other *p*; then connect them with moistened amianthus or cotton thread. If now the negative pole of the battery is connected with *n*, and the positive with *p*, the acid will pass over into the cup containing the distilled water—if the poles are reversed, the alkali will pass over into this cup. If instead of distilled water, infusion of purple cabbage be used, the presence of the acid will be detected by the red color which it will give to the infusion, and that of the alkali by its changing the infusion to green.*

But the effect in this experiment, and in those where three vessels are used, the middle one of which, although containing a very delicate test of the presence of an acid or of an alkali, will suffer them to pass through it without detection, can be accounted for on the principle that a part of the salt passes over into the cup by capillary attraction; as it has been proved by Fariday that decomposition never takes place unless the electric fluid actually passes through the substance.

It was in pursuing these researches that Davy made his great discovery of the decomposition of the alkalies and earths, which, until that time, had been considered simple bodies.

Theory. The theory of decomposition, proposed by Da-

Fig. 32.



* A very simple apparatus for showing the changes of color when salts in solution are subjected to Galvanic action, is shown in fig. 32, which consists of a glass tube, bent in the form of the letter U. Fill both legs with a neutral salt colored with the infusion of purple cabbage; on immersing the poles *p* and *n*, the color may be transferred from one leg to the other as often as the poles are changed.

vy, was this: He conceived that the poles of the battery were centres of attraction to one element of the compound, and of repulsion to the other; hence when the two poles were immersed in water, the oxygen of the water was attracted by the positive, and repelled by the negative pole, while the hydrogen was repelled by the positive and attracted by the negative pole. The elements, thus acted upon by four forces, were separated and made to appear at their respective poles.

But this theory does not account for all the phenomena. If it were true, we should expect decomposition to be effected by one pole alone, as it exerts the attractive and repellent influence, but this is never the case.

Mr. Fariday has lately revised this part of the subject, and not only added much that is new, but shown that many principles, especially the above theory, are erroneous. He contends that the poles have no attractive, or repulsive tendency, —but simply afford a path for the voltaic currents to enter the liquid. Instead of poles, he calls them *electrodes*,[*] which means the *way* or *door* for electric currents, and may be air, water, metal or any other substance capable of conducting the currents to and from the substance to be decomposed. The point where the positive current enters the liquid, he calls the *anode*,[†] and that where it quits it, the *cathode*.[‡]

When a compound is decomposed by galvanism, it is said to be *electrolyzed*,[§] and substances capable of decomposition are called *electrolytes*; the elements of an *electrolyte* are called *ions*[||]. *Anions* are the *ions* which appear at the *anode*. *Cations* those that appear at the *cathode*. The *anions* are the electro-negative substances, such as oxygen, chlorine, acids, etc. The *cations* the electro-positive, such as hydrogen, alkalies, metals, etc.

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[*] From ηλεκτρον and ὁδος, *a way*.

[†] From ἀνα, *upwards*, and ὁδυς, the way in which the sun rises.

[‡] From κατα, *downwards*, the way in which the sun sets.

[§] From ηλεκτρον and λυω, *to unloose* or *set free*.

[||] From ιον, *going*, neuter participle of the verb *to go*.

The following are the principal results of Fariday's investigations:

1. All compounds, contrary to what has been hitherto supposed, are not electrolytes; that is, are not *directly* decomposable by the voltaic currents. But many bodies may be decomposed by secondary action. Thus water is directly decomposed by an electric current; but nitric acid is decomposed by secondary action—the decomposition of the water contained in it, aids the decomposition of the acid. Very numerous secondary actions are produced in this way, because the disunited elements, separated by direct action, are presented in their nascent form, which is peculiarly favorable to chemical action.

2. Most of the salts or secondary compounds are resolvable into acid and oxide, but in the binary compounds, such as acids and oxides, the ratio of combination has an influence which has been hitherto overlooked. No two elements appear capable of forming more than one *electrolyte*. The proto-chloride of tin is readily decomposed, but the by-chloride is not. Hence substances which consist of *a single equivalent* of one element, and *two or more* of another, are not electrolytes; that is, are not decomposed *directly* by electricity.

3. Most of the simple substances are *ions*, that is, capable of forming compounds decomposible by galvanism.

4. A single *ion* by itself, has no tendency to pass to either of the *electrodes;* that is, it is indifferent to the voltaic currents.

5. There is no such thing as a transfer of the ions, in the sense supposed by Davy. In order that the elements of water should appear at the two electrodes, there must be a row of particles between them.

6. The air, or the surface of water may constitute an electrode, as well as metals.

7. Electro-chemical decomposition cannot occur unless a

current of electricity actually passes through the compound; that is, the compound must be a conductor of electricity. On this principle many substances, by change of state, resist decomposition. Water is easily decomposed, but ice is not; many solid substances also, are not *electrolytes*, because they are not conductors. Chemical compounds differ in the *electrical force* required for their decomposition; some require but a feeble current, others a powerful one.

9. The *conduction* of the electric currents in the cells of a battery depends upon *decomposition*. If the zinc or the copper be attacked chemically by a substance which is simple or a non-conductor, no currents can be set in motion.

10. Electro-chemical decomposition is perfectly *definite;* that is, in the voltaic circle 32.3 parts of zinc are dissolved during the the evolution of one part of hydrogen. This is in the ratio of their chemical equivalents. The same is true of all electrolytes. Hence Mr. Fariday has given to the quantities of electricity, requisite to effect the decomposition of various substances, the name of *electro-chemical equivalents*. This is a new and important discovery; it seems to prove, that the cause of chemical combination or affinity, is *electricity*. Hence, in order to estimate the *quantity* of electricity circulating in a voltaic apparatus, it is only necessary to collect the gas evolved from the acidulated water during any given time.

Theory of Electro-chemical Decomposition. We have already noticed the theory of Davy, which supposes that all substances are in one of two states of electricity, and that the poles have an attractive and repulsive force; but Mr. Fariday has shown that this theory cannot be true. All substances are indifferent when by themselves, but assume one of the two states when brought in contact. Only one substance is absolutely negative, *oxygen*, and but one absolutely positive, *potasium;* between these extremes, they may be made to assume either positive or negative states. To account for the decomposition of water, we must conceive of a line of particles between the two electrodes, along which the current passes. When a particle of oxygen is evolved at the positive electrode, its hydrogen is not transferred at once to the opposite electrode, but unites with the oxygen of the contiguous particle of water, on the side towards which the positive current is moving, then it passes to the next, and so on, until it arrives at the pole. A similar row of particles of oxygen start from the negative electrode at the same moment, and combine successively with the particles of hydrogen as they pass them on their way to the positive pole or electrode.* It is supposed that other compounds are decomposed by a similar process.

Magnetic effects of Electricity, or Electro-Magnetism.—History. It had been noticed for a long time that when a ship, for example, was struck with lightning, the magnetic needle often had its poles destroyed or reversed, and that the iron often became magnetic. This led to the supposition, that electricity might be employed to communicate the magnetic properties to iron or steel; but no results of importance were obtained until the winter of 1819, when Prof. Orestead of Copenhagen made his famous discovery, which forms the basis of a new and very important branch of science.

The discovery made by Orestead was, that the metallic wire, or any part of a closed voltaic circle, causes a magnetic needle, when brought near it, to deviate from its natural position, and assume positions depending upon the relative position of the needle and the wire.

Thus, suppose a magnetic needle freely suspended with its poles pointing north and south:—1. If now a positive current pass from north to south in the same plane with the needle, but a little above it, the north pole will turn to the east, and the south pole to the west. 2. If the current pass under the needle, the north pole moves west, and the south east. 3. If the current pass on the west side of the needle, and in the same horizontal plane, the magnet will have a tendency to move in a vertical direction, the north pole being elevated, and the south depressed. 4. If the current pass on the east side, the north pole is depressed, and the south elevated. 5. If the current flow from south to north, the needle will move in opposite directions. The deflection is rarely 45°, in consequence of the magnetism of the earth, but if that force is counteracted, as it may be, by suspending two magnets near each other of equal power, with their poles reversed, the declination will be 90°; hence *the tendency of a magnetic needle is to stand at right angles to an electric current.*

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* The quantity of electricity sufficient to decompose a single grain of water would be equal to a powerful flash of lightning.

If the wire be placed in a plane, perpendicular to the one in which the magnet moves, and the positive current ascends or descends to the centre of the needle, no action will take place; but if it be moved towards the north or south poles, they will be attracted, or repelled. *Hence the plane in which a needle moves is always perpendicular to that in which the voltaic currents circulate.*

The phenomena of *Electro-Dynamic action* result wholly from electricity in motion, and depend upon quantity alone; hence a few large plates are best fitted for exhibiting it.*

From the above facts it will be seen, that the magnetic needle may be employed, not only to ascertain the existence and direction of voltaic currents, but also to measure their force. The instruments used for these purposes are called *Galvanometers* or *Multipliers.*

As it is proved by experiment that every part of a wire in a closed circuit exerts an equal force upon the poles of a needle, if we can increase the number of points, the combined force will be greatly increased. This can be done by coiling the wire into the form of a circle or rectangle; each coil will exert its own force, independent of its neighbor, and the uni-

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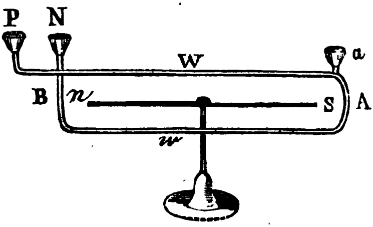
* The simple battery, fig. 27. p. 74, is best fitted for experiments on this subject. The exciting liquid should be a solution of sulphate of copper.

Fig. 33.

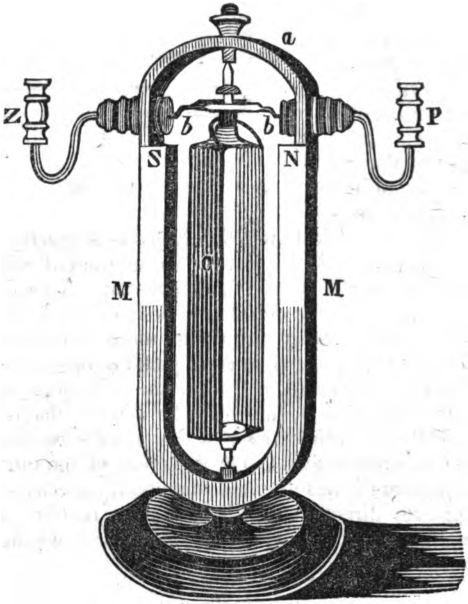


ted force will depend upon the number of coils. Thus (fig. 33), NP are the two ends of a copper wire bent in the form of a rectangle, in the centre of which, and in a plane perpendicular to the plane of the wire, is placed a magnetic needle—this constitutes the ***Electro-Magnetic Multiplier*** of Schweigger. By increasing the number of coils, the deflection of the needle will be much greater. A graduated circular plate measures the degree of declination, which indicates the quantity of electricity circulating along the wires. It will be seen, that if the positive current pass above the needle from north to south, that is, from P to *a*, and then pass around the south pole from A to B, there will be double the effect produced. If the *directive* power of the needle be destroyed, it will stand at right angles to the direction of the currents; or if at the moment it has attained this point, the currents be sent in an opposite direction, it will perform a revolution. Thus, by changing the direction of the currents, a needle may be made to revolve rapidly.

If the magnet is fixed, and the rectangle suspended free to move, it will exhibit the same phenomena while the voltaic currents are passing around it. The *Revolving Rectangle* is constructed on this principle.

MM (fig. 34.) is a permanent horse-shoe magnet; C a rectangular coil of copper wire, connected at each end to an axis, by which means it may be made to revolve; ZP are two cups to form a connection with the poles of a battery; the wires *bb* are connected with the cups, and press on opposite sides of the cylindrical metallic *pole-changer*, which revolves between them. The pole-changer consists of two pieces of copper or steel, with a small space called a *break*, between them; one of these pieces is connected with one end of the wire of the rectangle, and the other piece with the other end; *a* is an arch of brass to support the rectangle and the wires. If the two cups be connected with the battery, P with the positive,

Fig. 34.



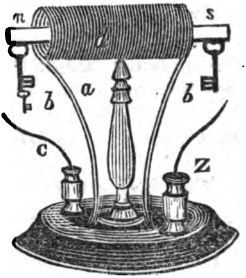
and Z with the negative pole, the positive current will pass along the wire *b* next to N, and from the wire to one side of the pole-changer, and thence several times around the rectangle to the wire *b* next to S.

When the positive current is passing from P around this rectangle, one side is impelled towards one pole of the magnet, and the other towards the other pole. When the sides arrive in the plane of the poles, they acquire sufficient force to pass by, and complete half a revolution, standing again at right angles to the poles of the magnet: at this point the pole-changer sends the currents in opposite directions, and the revolution is continued. Reverse the current, by changing the battery wires, and the rectangle will revolve in an opposite direction.

The influence of voltaic currents on soft iron and steel **was noticed by Davy and Arago about the same time. If an iron**

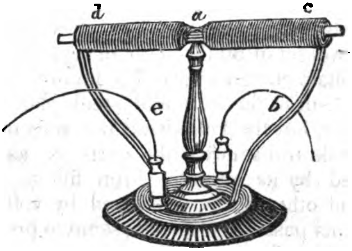
or steel needle be suspended in the galvanometer instead of the common needle, at right angles to the conducting wires, permanent magnetism will be communicated to the steel, and the iron will become powerfully magnetic, as long as the currents circulate; but will lose this property when the circuit is broken. Davy succeeded in producing a similar effect by a discharge from a common electric battery.

Fig. 35.



This effect can be exhibited in the most satisfactory manner by coiling an insulated copper wire in the form of a helix *d* (fig. 35.), and connecting the two ends of the wire *bb* with the cups CZ, into which the poles of a battery may be inserted. Bars of soft iron or steel placed in the coil, will become magnetized the instant the voltaic currents circulate around the coil. If the positive current flows from Z around the helix, *n* will be the north pole, and *s* the south pole. If it flow from C, the poles will be reversed.

Fig. 36.

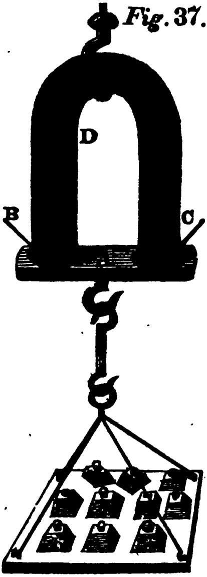


If a bar of soft iron (fig. 36.) be wound with copper wire from *c* to *a* in one direction, and from *a* to *d* in an opposite direction, and currents of electricity passed around the bar, by connecting the wires *b e* with a voltaic battery, the bar will have three poles; *c* and *d* will be similar poles, and *a* an opposite pole common to the other two, as may be shown by bringing a magnetic needle near each. By changing the direction of the battery currents, the poles are reversed; ***hence the kind of pole depends upon the direction of the voltaic currents.***

Although soft iron does not retain its magnetism, yet its magnetic properties while the voltaic currents are passing around it, are truly surprising.

If a soft iron cylinder two inches in diameter, and bent in the form of a horseshoe magnet D (fig. 37.), be wound with copper wire, and the ends BC connected with the battery, it will be converted into a powerful magnet. On applying the armature A, it will sustain several hundred pounds. Magnets of this description, may be made to sustain from 200 to 2000 lbs. It will be seen that the principle is the same as in the *helix*.

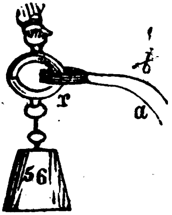
Fig. 37.



The Magic Circle, with two iron armatures, acts also on the same principle.

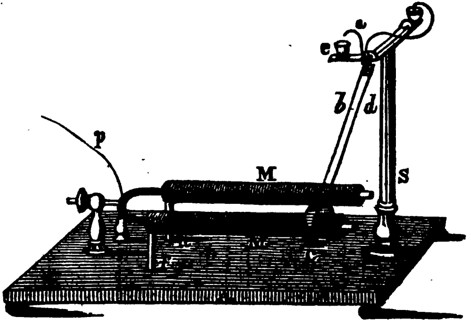
r (fig. 38.) is a coil of insulated copper wire; *ab* the two ends which may be connected with the battery. When the two armatures are brought into contact, one of them passing through the ring, they adhere to each other very strongly, and although they weigh less than ¾ lb., they will sustain a weight of 50 lbs. without separation. The voltaic currents not only communicate magnetism to the iron and steel placed in the ring, but the helix itself becomes magnetic while transmitting the currents, as is proved by its attracting iron filings. These and other facts, developed by voltaic currents passing in circles, seem to prove the *identity* of the magnetic and electric fluids.

Fig. 38.



Vibrating Magic Circle. MM (fig. 39.) is an *electro-magnet*, which may be used instead of a permanent magnet; *c* a coil of coarse wire suspended from the post S; one end of the wire *a* dips into the cup *e*, which is connected with the post S, and which also communicates with *p*; the other end of the wire *d* is connected with the other cup, which is insulated from

Fig. 39.



the post S, and into which also one of the poles of the battery may be immersed; connect the other pole of the battery with *p*, and a current of electricity will pass along the post S to the cup *e*; as the wire *a* dips into it, the current will pass down the wire *b* around the coil *c*, and then up the wire *d* to the other cup; as the currents circulate, the coil will be attracted to the pole of the magnet M; this will lift *a* and break the circuit, and the coil will fall back beside the post S; *a* will again be immersed in *e*, and the coil be again attracted upon M. Thus vibrations are produced as long as the currents circulate.

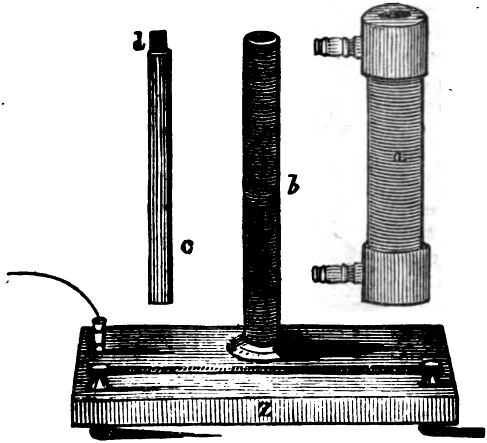
Volta-Electric Induction. The fact that an electrically excited body induced electricity in other bodies brought near it (page 69), led Faraday to inquire whether electricity in motion would not have the same effect. This fact he soon established.

If a copper wire be wound around a block of wood so as to form a helix, and the ends connected with a battery, and then another wire be wound around this, but insulated from it, and the ends connected with a galvanometer, currents of electricity will be induced in the insulated wire, as often as the battery current is broken. All the effects of galvanism may be produced by the insulated wire. This phenomena is called ***Volta-Electric Induction.***

If a bundle of soft iron wires be placed in the coil, the effect will be greatly increased. This may be illustrated by the following apparatus:

b (fig. 40.) is a hollow coil of coarse wire fixed upon a stand Z; one end of the wire is connected with the cup, and

Fig. 40.



the other with the steel break-piece, which is fixed to the stand by the side of the coil; *a* is a coil of fine wire, which may be placed over the coil *b*; *d* is a bundle of wires which may be slipped into the copper case *c*, and placed in the centre of the coil *b*.

Fig. 41.

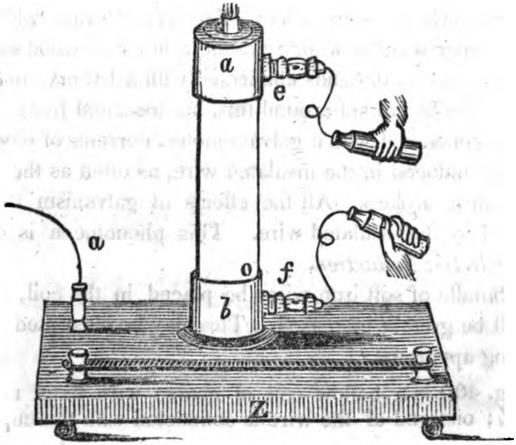
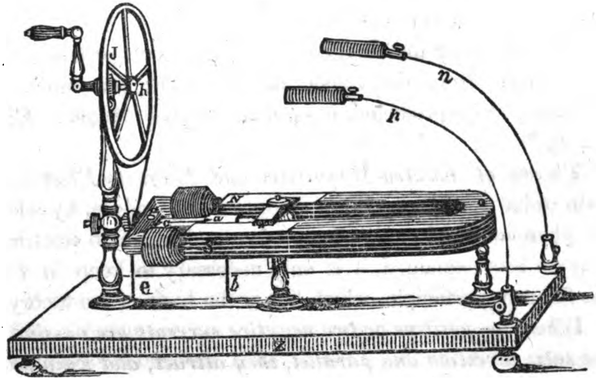


Fig. 41 represents this apparatus entire. *Exp.* Connect one pole of the battery with the cup *a*, and move the other along the break-piece, vivid sparks will be produced. *Exp.* Remove from the wires *d* the copper case *c*, and insert it gradually in the coil while the currents are circulating, and the sparks will increase by degrees till it reaches the bottom, when the greatest effect will be produced. *Exp.* If the handles *e f*, which communicate with the coil *o* be held in the hands, powerful shocks will be felt as the wire passes across the break-piece, and these will be diminished by removing the wires. *Exp.* If the copper case be placed upon the wires, the effect will be the same as when the wires are not inserted. A single wire will increase the power of the shocks, and by increasing the number of wires, the sparks will increase in brilliancy, and the shocks will become more and more powerful; hence it is called an *Apparatus for the Analysis of shocks and sparks.*

Magneto-Electric Induction. The inducing power of the magnet greatly exceeds that of voltaic currents.

Fig. 42.



The apparatus best fitted to exhibit this effect, is the *Magneto-Electric Machine* (fig. 42.), which consists of a permanent horse-shoe magnet. SN supported by pillars upon the stand Z, and an armature *g* wound with copper wire, and made to revolve upon an axis *c*, near the poles of the magnet, by means of the wheel *h*; one end of the wire is soldered to the axis, by which means it is connected with a break-piece, against which the wire *e* presses; the other end of the wire is soldered to a silver ferule *a*, insulated from the axis against which the wire *b* presses; the wires *e b* communicate with the two cups into which the wires *p n* are inserted. When the armature is set in motion by the multiplying-wheel *h*, its magnetic state is continually changing. When the two extremities of the armature are midway between the poles of the magnet, the armature is neutral. As they advance towards the poles, they acquire a gradually increasing polarity until they are opposite the poles, and gradually diminish as they pass the poles until they are midway again between the poles, when the armature becomes neutral as before. By this revolution, a current of electricity will be induced in the wire which surrounds the armature, and will pass from the break-piece to the ferule, by means of the wire which connects them; excepting, when the end of the wire is passing across the break-piece, then there will be induced in the wire a secondary current, which passes by sparks at each point of interruption. By pressing the hands, previously moistened, upon the handles connected with *p n*, powerful shocks will be felt at each interruption.

The electricity thus induced produces effects precisely similar to those from the voltaic battery. The phenomena of electricity, thus produced, is sometimes called *Magneto-Electricity.*[*]

Theory of Electro-Magnetism and Magneto-Electricity.—In order to understand the theory of M. Ampere, by which the phenomena of electro-magnetism and magneto-electricity may be best explained, it is only necessary to keep in view the following principle, which lies at the basis of the theory.

When two positive or two negative currents are passing in the same direction and parallel, they attract, and when passing in opposite directions, they repel each other.

If now we suppose that all magnetic bodies, and the earth itself among the number, derive their magnetic properties from currents of electricity circulating in reference to their axis in one uniform direction of revolution, we can account for all the phenomena of ***Magnetism, Electro-Magnetism*** and ***Magneto-Electricity.***

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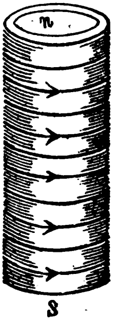
[*] The best apparatus for experiments upon Electro-Magnetism and Magneto-Electricity, is manufactured by Daniel Davis, Jr. No. 11 Cornhill, Boston.

Fig. 43.



To make this view clear. Suppose that around the cylinder of steel (fig. 43.), at right angles to the axis, currents of positive electricity are constantly circulating in a direction opposite to that in which the sun moves. The cylinder will be a magnet, *n* the north pole, and S the south pole, and if it be poised upon a pivot, it will differ in nothing but in form from a magnetic needle.

Application of the Theory. 1. The reason that the needle turns to the east when the positive current passes above it from north to south is, that then the currents in the magnet, and those in the wire, will move in the same direction.

2. When the positive current passes under the needle, it moves to the west, because then also the two positive currents coincide.

3. When it passes on either side in the same horizontal plane, it tends to a vertical motion, for the same reason as above; but if the positive current passes from north to south, the phenomena are all reversed.

4. When it passes around the poles in a vertical plane, in the same direction in which the sun appears to move, the needle will perform one half a revolution, because the currents move in opposite directions, and the needle revolves so that the currents in it may coincide with those in the conducting wire.

5. Steel and soft iron become magnetic when placed in the helix around which currents of electricity circulate, because similar currents are *induced* in them.

6. If we suppose positive currents of electricity to be passing around the earth in the same direction in which the sun appears to move, they would convert it into a magnet, the north pole of the earth corresponding to the south pole of the magnetic needle; hence if soft iron or steel are placed in a north and south direction, they will become magnets by *induction*, the positive currents passing from west to east, because then they would coincide with the same currents in the earth which pass from east to west.

Thermo-Electricity. Thermo-electric phenomena result from currents of electricity excited in metals by heat. The existence of these currents was first demonstrated in 1821 by Seebeck.

If a magnet be suspended in a rectangle formed of a bar of antimony or bismuth, having its extremities connected with copper wires, and heat applied to one end of the bar, the needle will be deflected in one direction, and in an opposite direction when heat is applied to the other end. Similar effects are produced when either end is cooled below the natural temperature. Other metals treated in the same manner, exhibit similar phenomena, but bismuth and antimony are the best. Prof. Cumming has shown, that a rotary motion may be produced by placing platinum and silver wires, soldered together in a circular form upon a magnet, and applying heat.

Nature of Electricity. Some suppose that there is no transfer of *anything* in what are called electric currents, but a process of *induction* passing progressively along among the molecules of a conductor. Others ascribe them to waves of vibrating matter, just as the phenomena of light, and caloric are explained, by the undulatory theory.

PART II.

CHEMICAL AFFINITY.

In all those phenomena, which appropriately come under the observation of the chemist, chemical affinity is the great cause to which they are referred. Other agents, as light, heat, electricity, cohesion, etc. modify its action, and some knowledge of them is therefore an essential preparation for the study of this,—the great subject of chemistry. The details, to which we shall attend in the examination of particular substances, are, almost exclusively, but the effects of this principle. The student, therefore, should be familiar with the circumstances which modify its action, its varieties or different modes of operation, its effects, and especially the laws in accordance with which these effects are produced.

Chemical Affinity is an attraction, which acts only *at insensible distances, between particles of different kinds.*[*] Cohesion is distinguished from it, by acting only between particles of the *same kind*, as well as by being governed by different laws.

Varieties of Chemical Affinity.

Although this power is the same in all cases, it will facilitate the progress of the student to distinguish some of the different cases in which it operates. Between many substances it does not exist at all, as is seen in mixing oil and water. The most simple case is the direct union of two substances, as when oxygen gas and iron unite, and form iron rust. This is called *Simple Affinity.* The combination of alcohol with camphor is another example.

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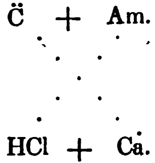
[*] A late writer (Griffin, Chemical Recreations) maintains that there is no such thing as chemical affinity, because we know merely that bodies combine. We might as well deny that any force or power exists because we see only its effects. From the fact that bodies do combine, we infer that some power causes them to combine, although indeed we know nothing of it except in its effects.

Exp. But if water be added to this solution of camphor, the alcohol will combine with the water, and desert the camphor, which again appears free, or is technically said to be *precipitated.* As the alcohol appears to choose the water in preference to camphor, such cases are called examples of *single elective affinity.*[*]

But in other cases, two compounds mutually decompose each other, and form two new compounds.

Exp. Thus, if carbonate of ammonia and hydrochlorate of lime be mingled, each will be decomposed. The former consisting of carbonic acid and ammonia, and the latter of hydrochloric acid and lime, the carbonic acid will unite with the lime, and the hydrochloric acid with the ammonia, forming carbonate of lime, and hydrochlorate of ammonia. This change may be very easily understood from the annexed formula, in which the symbols are used.[†]

$\ddot{C}$ abandons Am. and goes to $C\dot{a}$.—at the same time HCl abandons $C\dot{a}$. and goes to Am. and the results are $\ddot{C}+C\dot{a}$. and HCl+Am.



Such cases are examples of *double elective affinity.*[‡] Cases are more numerous, however, in which the changes are much more complicated.

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[*] *Elective Affinity* is the basis of chemical science, for if each substance attracted every other with the same force, when combination had once been effected, the decomposition of many, if not of most substances, would be impossible; hence there would be but few changes in matter which would come under the investigation of the chemist.

[†] $\ddot{C}$ = Carbonic acid, and Am.=Ammonia; HCl=Hydrochloric acid, and $C\dot{a}$. = Lime.

[‡] *Single* and *double elective Affinity* are the same in principle. The only difference is, that in the one case, a compound is decomposed by

Circumstances which modify the operation of Chemical Affinity.

That one substance has a stronger affinity for some than for others cannot be doubted. But combination and decomposition do not always depend upon the relative force of affinity alone. Several circumstances modify the operation of this power. These are cohesion, elasticity, quantity of matter, gravity and the imponderable agents.

Cohesion. In order that substances should combine with each other, it is necessary that their particles should be in contact. But cohesion holds together the particles of each substance, so that they cannot be freely intermingled. Cohesion must, therefore, be destroyed to facilitate chemical action. This may be effected in three ways:

1. By reducing the substance to powder.

Exp. Take two equal portions of chalk, and pulverize one; pour dilute sulphuric acid on each, and the action will be rapid in the case of the pulverized chalk, but moderate in the other case. In this experiment one of the substances is in solution, and usually it will be found insufficient to pulverize both substances, and resort must be had to the second method.

2. By solution. *Exp.* Mix together tartaric acid and carbonate of soda; no action will follow; pour on water, and they will be dissolved, and a violent action ensue.

Solution is effected, when a solid is put into a liquid, and entirely disappears, leaving the liquor clear. The body which thus disappears is said to be *soluble;* the liquid is called a *solvent*, and the compound liquor a *solution.* Water is the principal solvent; alcohol, ether, oils, alkalies, and acids are also employed. When water, or any solvent has dissolved as

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a third substance, and but two affinities are in operation, while in the other, two compounds mutually decompose each other, and four affinities are brought into action.

much of any substance as it can, it is said to be saturated, and the solution is called a saturated solution. Solution should not be confounded with diffusion, which is mere mechanical mixture. This distinction may be seen by mixing magnesia in water. The particles of magnesia are suspended at first in the water, rendering it turbid, and they would soon subside to the bottom; but if nitric acid be added, the magnesia will be dissolved, and the water will become clear.

Most substances are more soluble in hot than in cold water; as a hot saturated solution cools, the water will not therefore be able to hold in solution all of the substance which had been dissolved, and it appears again in a solid state. The power of cohesion has the ascendancy over the affinity of the liquid for the solid, and forms the latter into crystals. Hence the *phenomena of crystallization* are owing to the ascendancy of cohesion over affinity.

By evaporation, also, the solid may be recovered from solution. In either case, the crystallization is often confused, especially when the process is rapid.

Insolubility has been found to exert a remarkable influence on affinity, in the case of an alkali with two acids, or an acid with two alkalies, one of which will form with the alkali a soluble, and the other, an insoluble compound. The one which is insoluble is always formed in preference to the soluble compound.

Exp. Thus if nitric and sulphuric acids and baryta be thrown together in water, sulphate of baryta, which is *insoluble*, will be formed in preference to nitrate of baryta, which is *soluble.*

It is obvious that while the solution of one of the substances is usually necessary, the solution of both will further facilitate the action.

3. By heat. *Fusion* is the reduction of a solid to a liquid state by caloric, and facilitates chemical action by enabling the particles to intermingle, and come within the sphere of

each other's affinity. In liquids a slight degree of cohesion remains, and hence heat is applied to them with advantage. A hot liquid will act more powerfully upon a solid than the same liquid when cold.

Elasticity. Cohesion, as we have seen, opposes chemical action by keeping the particles out of the sphere of each other's influence. Elasticity, or the gaseous state, is still more unfavorable to the operation of affinity, because the particles are removed too far from each other to be attracted; hence most gases, though possessing a strong attraction for each other, will not combine unless they are in the nascent state, that is, when in the act of assuming the gaseous form.

In this way elasticity not only prevents chemical union, but it favors decomposition. When two highly elastic gases combine, forming a liquid or solid, the compound will be decomposed by a very slight cause—the *chloride of nitrogen* is a familiar example. It is an oily liquid composed of two gases. A slight elevation of temperature will cause instant decomposition, even with explosive violence. Generally all compounds which contain a volatile principle are easily decomposed by a high temperature. Hence caloric sometimes favors *chemical action by destroying cohesion*, while at others it *prevents it, and favors decomposition* by promoting *elasticity.*

There are some gases, however, which readily combine at a high temperature, as in the case of *gaseous explosive mixtures.* Oxygen and hydrogen gases require the heat of flame to effect their union. The caloric in such cases, according to Berthollet, expands the gases in immediate contact with the flame, which acts as a violent condensing force to contiguous portions, and brings them within the sphere of each other's attraction. The same explanation is applied to the combination of gases effected by passing electric shocks through them.

Quantity of matter. Oxygen combines with lead in three proportions, forming three distinct compounds. The peroxide, or that which has the greatest quantity of oxygen, is easily decomposed by heat; the second compound, in which there is less oxygen, requires a higher temperature to effect decomposition; and the third, which has the least oxygen, will sustain the heat of our furnaces without yielding up its oxygen.

Generally, when one substance combines with another in several proportions, the affinity is stronger in the case of the *less* than of the *greater* portions.*

On this principle also, when a salt is dissolved in water, the first portions are dissolved more rapidly than the last, and the force of affinity diminishes up to the point of saturation, when it is overcome by the cohesion of the solid.

This principle led Berthollet to account for all chemical changes without the aid of affinity, the existence of which he was disposed to deny, but M. Dulong has found that the principle of Berthollet is not in accordance with the results of experiment.

Gravity. The influence of gravity on chemical action is seen when substances of different *specific gravities* combine. As when two liquids are put together, the heavier liquid will sink to the bottom; or when salt is dissolved in water, the salt will remain at the bottom, and prevent the particles of water from coming into contact with those of the salt.

Imponderable agents. The influence of caloric over chemical phenomena has already been alluded to. It favors chemical action in the case of solids, by destroying cohesion, and opposes chemical action in the case of gases, by increasing their elasticity. The influence of light has already been noticed. Common electricity is often employed for the combination of gases, and galvanism for decompositions, but the same effects may be produced by either.

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* In consequence of the influence of quantity of matter over chemical changes, the chemist generally employs more of one substance, than is necessary, to effect the decomposition of another.

Measure of Affinity.

Since some substances have a stronger affinity than others. attempts have been made to measure its different degrees of force. It was once supposed that its relative strength could be ascertained by the order of decomposition, as may be explained from the following table:

Sulphuric acid.

Baryta,
Strontia,
Potassa,
Soda,
Lime,
Ammonia,
Magnesia.

If to the sulphuric acid, united with the magnesia, forming the sulphate of magnesia, ammonia be added, the acid will leave the magnesia, and elect the ammonia, forming the sulphate of ammonia. If to this, lime be added, the acid will desert the ammonia, and unite with the lime; this again will be decomposed by the soda, and so on to baryta. Hence sulphuric acid has the strongest affinity for the baryta, and the force is in the order in which the several substances are arranged; hence the practical chemist, when he wishes to decompose any compound, is enabled to decide upon the substance which will produce that effect.

But the circumstances which modify the action of chemical affinity are so numerous, that the *order* of decomposition is not, in every case, the *measure* of affinity. To determine the relative force of affinity in doubtful cases, observe the tendency of several substances to unite with the same, under the same circumstances; and then notice the apparent facility of decomposition when these compounds are exposed to the same decomposing agent.

Effects of Affinity.

The changes which accompany the action of affinity, are changes of chemical properties, of color, form, temperature, and specific gravity.

I. *Change of chemical properties.* It is one of the most remarkable facts in chemistry, that when two bodies combine chemically, the compound is *generally* possessed of properties entirely different from those of the components.

Exp. 1. Pour sulphuric acid upon magnesia, and the compound will be Epsom salts, entirely unlike either.

Exp. 2. Burn oxygen and hydrogen gases, and water will be formed, which is wholly different from either of its constituents.

There are some cases in which affinity produces compounds without much change of properties, as in the case of *solution*, but the force of affinity in such cases is very feeble.

Exp. Salt dissolved in water, and camphor in alcohol, are instances.

II. *Change of color* is often the effect of affinity.

Exp. 1. To the chloride of calcium, add nitrate of silver, both in solution; a white precipitate will be formed, which is the chloride of silver. (See page 62.)

Exp. 2. To a solution of nitrate of lead, add a few drops of hydriodic acid, and a beautiful yellow pigment will be formed.

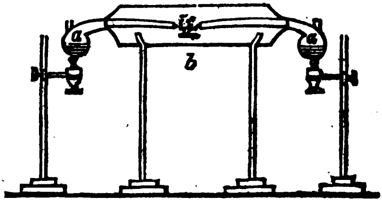
Exp. 3. Into an infusion of purple cabbage, pour a few drops of any alkali, and the color will become green; add an acid gradually, drop by drop, and the purple color will be restored; add a few drops more of acid, and it will become red. By the gradual addition of the alkali, the effects may now be reversed.

III. *Change of form* frequently accompanies chemical combination.

Exp. 1. Take oxygen and hydrogen gases, and explode them; they will form a liquid, water; hence chemical affinity converts gases into liquids.

Exp. 2. If the two gases, ammonia and the hydrochloric acid, be brought together in their nascent state, i. e. at the moment of their formation, they will produce the solid hydrochlorate of ammonia. Hence, chemical affinity con-

Fig. 44.



verts gases into solids. The two gases may be formed by putting hydrochlorate of ammonia and lime in one retort, (fig. 44.) and liquid hydrochloric acid in the other, and applying heat; as the gases meet in the glass receiver *b*, they will combine and form a white solid.

Exp. 3. Take chloride of calcium in solution, and pour in sulphuric acid; a solid precipitate the sulphate of lime will be thrown down. Hence affinity converts liquids into solids.

Exp. 4. Into a solution of pearlash or saleratus, pour sulphuric acid, and a portion of the liquid is converted into the form of a gas, which escapes with effervescence. Hence, affinity converts liquids into gases.

Exp. 5. Mix two solids, the nitrate of ammonia, and sulphate of soda; on rubbing them in a mortar, they will become liquid. Hence chemical affinity converts solids into liquids.

Exp. 6. Explode gun-powder, it will be converted into gas. Hence chemical affinity converts solids into gases.

IV. *Change of temperature.* The heat arising from the combustion of fuel, is owing to chemical action.

Exp. Wet a piece of paper with spirits of turpentine and sulpuric acid, and then throw on a few grains of chlorate of potassa; the paper will instantly be in flames.

V. *Change of specific gravity.* In changes of gases into liquids or solids, or of the latter into the former, there is, of course, a great change of density. But where there is no change of form, there is usually more or less of this change.

Exp. Mix 100 measures of strong sulphuric acid with 100 of water, and the mixture will be less than 200 measures.

Laws of Chemical Affinity.

The laws which regulate the action of affinity, constitute the most important part of the whole subject, for they are the foundation of modern chemistry. As they are expressed mathematically, they have consequently imparted to it a high degree of accuracy, and greatly elevated its rank as a science. Most substances have been found to combine in definite proportions, and with such, the laws of affinity are chiefly concerned; but there are numerous cases of apparently indefinite proportions, which first demand a separate consideration.

I. *Indefinite proportions.* Of these there are two cases, in the first of which, any quantity of one substance may be combined with any quantity of another. Thus a drop of alcohol will combine with a quart of water, or a drop of water with a quart of alcohol. In the second case, the proportions are indefinite within certain limits. Thus with 2½ lbs. of water, a pound or any less quantity of common salt will combine, but if a larger quantity of salt be employed, all the excess above a pound will remain undissolved. The limit to the process is the point of saturation. (See page 99.)

The most common instances of indefinite proportions are solutions, where the proportions are indefinite below the point of saturation. Instances of unlimited indefinite proportions are less numerous. It is important to observe in these cases, that the force of affinity is usually feeble and the change of properties slight. Thus in the common liquors, the properties of the alcohol are slightly modified by its combination with water, and in solutions there is also little change.

II. *Definite proportions by weight.* In the most numerous and interesting cases of chemical combination, a certain portion of one substance unites with one, two, three, or more times a given weight of another. These cases are usually characterized by a greater energy of combination, and a much greater change of properties than those which have been described. The great law of definite proportions by weight may be thus expressed:

The proportions, in which substances combine, may be expressed by fixed numbers, or by the multiples of these numbers. The following table is an illustration.

Water	is composed of	Hydrogen	1	part	+	Oxygen	8	parts.
Binoxide of Hydrogen	“	“	1	“	+	“	16	“
Protoxide of Nitrogen	“	Nitrogen	14	“	+	“	8	“
Binoxide “	“	“	14	“	+	“	16	“
Hyponitrous acid	“	“	14	“	+	“	24	“
Nitrous acid	“	“	14	“	+	“	32	“
Nitric acid	“	“	14	“	+	“	40	“

A comparison of all the cases shows that hydrogen enters into combination in less quantity relatively than any other substance. It is therefore taken for a standard of comparison, and in the above table appears as unity. The lowest ratio in which oxygen combines with other substances is eight times that of hydrogen. The lowest combining ratio of nitrogen is fourteen. If any simple substance does not combine with hydrogen, its lowest combining ratio may be ascertained from its combination with any other substance, whose ratio has been determined. Thus from the above table the combining ratio of nitrogen is seen in its compounds with oxygen, whose ratio was ascertained in its compounds with hydrogen. The *lowest combining ratio* is also called an *equivalent*, or *proportional.*

Inspection of the above table will show, that while eight is the lowest combining ratio of oxygen, it combines also in the ratio of 16, 24, 32, and 40 parts; that is, two, three, four and five times the lowest ratio, agreeably to the above-mentioned law.

There are some cases in which substances do not unite with one equivalent of one, to one, two, or more equivalents of another, but apparently of one to one and a half. Such an irregularity conforms to the general law on the supposition that two of the former unite with three of the latter. In some cases also two equivalents of one substance unite with five of another.

The law of definite proportions by weight may be thus illustrated algebraically. If x and y be the equivalents of any two substances, their compounds must be $x+y$, $x+2y$, $x+3y$, $x+4y$, etc.; sometimes we shall have $2x+3y$, and rarely $2x+5y$.

It is evident from the above that *the equivalent of any compound is the sum of the equivalents of its constituents*, each being multiplied by the number of times it enters into the combination. Thus in the above table the equivalent of water is $1+8=9$, of nitric acid, $14+40=54$, etc.

The second law of definite proportions is the following: *Every substance has its constitution invariable.* Thus nitric acid is always composed of one equivalent of nitrogen and five of oxygen. No other substances, and no other number of equivalents of these, by combination can form nitric acid.

The laws of definite proportions were discovered by Dr. Dalton, an eminent English chemist. The application of them in the arts is of immense importance. In the manufacture of compounds, they teach precisely what proportions of the ingredients should be used. If these are expensive, an excess of one would be a serious loss.

III. *Definite proportions by volume.* The principal law of definite proportions by volume is precisely similar to that of definite proportions by weight, the parts being determined by measure as in the former case by weight. This law holds true only in the case of gases and vapors. It is supposed that substances, which have not yet been made to assume the form of a gas or vapor, would conform to this law, if they should assume such form. The law may be illustrated by the following table.

100 vols.	carbonic acid	gas	combine with	100	of ammoniacal gas.
"	"	"	"	200	"
"	fluoboric	"	"	100	"
"	"	"	"	200	"

But there are two laws of definite proportions by volume, which do not hold true in definite proportions by weight. The first is that a simple ratio exists between the volumes of different constituents in the same compound. This may be seen in the above table.

The second law is, that in combination, gases and vapors are condensed by a portion, which is in a simple ratio to the volume of one of the constituents.

The laws of definite proportion by weight and by volume are not inconsistent with each other, for the specific gravity always bears such a relation to the combining ratio by volume as to establish their harmony. Thus hydrogen and oxygen combine in the ratio of two of the former to one of the latter by volume, and of one to eight by weight. But as oxygen is sixteen times heavier than hydrogen, one volume of it is eight times as heavy as two of the latter. In other words, the compound ratio of the specific gravity and of the equivalents by volume, is equal to the ratio of the equivalents by weight.

Atomic Theory.

Existence of Atoms. The atomic theory supposes matter to be composed of minute, indivisible atoms. Hypothetically, matter is infinitely divisible, that is, to Almighty power; but in fact it is not infinitely divided. Sir Isaac Newton regarded it as probable, "that the primitive particles, being solids, are incomparably harder than any porous bodies compounded of them, even so very hard as never to wear, or break in pieces; no ordinary power being able to divide what God himself made one in the first creation."

Theory of definite proportions by weight. When substances combine in their lowest equivalents, they unite atom to atom; in higher proportions, one atom of one to two, three, or more atoms of the other. This theory exactly accounts for the facts of definite proportions; for if in one compound we have one atom of A joined to one of B, and in another one of A joined to two of B through the whole mass, the sum total of B in the latter case will be exactly twice as much as in the former case.

Atomic weight. If in a compound of one grain of hydrogen with eight of oxygen there be an equal number of atoms of each, an atom of the latter will be eight times as heavy as an atom of the former. In this way we know the relative weights of the atoms of all substances, whose equivalents are known. As the numbers are the same, the terms are often interchanged.

The *absolute weight*, and *magnitude* of atoms cannot be determined. Dr. Thompson calculates that a cubic inch of lead contains more than 883,492,000,000 atoms.

The *shape* of atoms is matter of hypothesis. They are generally supposed to be spheroidal.

Cause of Chemical Affinity.

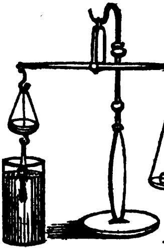
The cause of affinity is probably *electricity*. In those cases where the electrical state of substances can be ascertained, they are always found to be oppositely electrified, when combination takes place. Voltaic electricity is the most powerful decomposing agent, and the whole phenomena of electro-chemical decomposition seems to prove the *identity* of affinity and electricity. This view accords best with the simplicity everywhere observed in the laws of nature. By ascribing the phenomena of electricity, galvanism, magnetism, and chemical affinity to the same agent, we seem to be progressing in the chain of causation nearer to the great and ultimate cause, the agency of God. Some suppose, that what we call the agents, and laws of nature, have no real existence as distinct powers. They deny the agency of *second causes*, and ascribe every operation of nature to the immediate power of God. Others suppose that there are real agents or causes dependent upon God; but possessed of power in themselves, to act as *second causes*, or *subordinate* agents, in the various phenomena of matter. Whichever view we take, we must in the end refer the ultimate cause to the impulse of the Divine will; although for the mere purposes of scientific classification, something perhaps is gained by the introduction of second causes.

PART III.

PONDERABLE BODIES.

Specific Gravity means the relative weight of different substances, compared with some standard. In the case of solids and liquids, the weight of the body is compared with water as unity; i. e. if a given quantity of water by *measure* be weighed, and that weight represented by one, the weight of an equal quantity by measure of any other substance is compared with it. In the case of gases, air is taken for the standard of comparison, or for unity, and an equal quantity of any other gas is weighed, and compared with it.

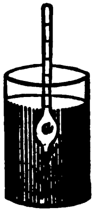
Fig. 45.



There are several methods of ascertaining the specific gravities of bodies. One of the best, if the body is a solid, is to weigh it in the air, and then in water, in a manner represented in fig. 45. If the body weighs 100 grains in the air, and 60 grains in water, then to ascertain its specific gravity, institute the following proportion: as 100—60, or 40 : 100 : : 1 : 2.5; hence the sp. gr. of the body is 2.5, or two and a half times as heavy as water. If the solid is lighter than water, suspend to it a body heavier than water, whose specific gravity is known, and then weigh it as in the first instance.

To ascertain the specific gravity of liquids, the *Areometer* is a convenient instrument. It consists of a tube *a* (fig. 46.) graduated with numbers, upon the end of which are two balls, the lower filled with mercury. If the instrument sink in distilled water to 1, it will sink below that mark in liquids which are lighter than water, and will remain above it in those

Fig. 46.



which are heavier. The specific gravity of each liquid is thus ascertained by the numbers on the scale. The specific gravity of liquids is also ascertained by the use of a small bottle containing just 100 grains of water; by filling it with any other liquid, its weight will express directly its specific gravity.

The specific gravity of gases is more difficult; a given portion of air is carefully weighed for unity, and the weight of an equal quantity of any other gas is compared with it.

Nomenclature.

The study of particular substances has been greatly facilitated by the introduction of the nomenclature. By the use of systematic *names, expressive of the constitution* of substances, the recollection of the name will call to mind the constitution, while on the other hand, if there be any difficulty in remembering names, the constitution will at once show what the name must be. Hence, although compounds are very numerous, the student can have no difficulty in remembering their names and constitution, for the one necessarily suggests the other.

The present nomenclature was introduced in 1787 by the French chemists. Since that time it has undergone but a few slight changes. The former nomenclature, if such the entire want of system could be called, was barbarous in the extreme; fanciful names were introduced, and often many such were attached to the same substance.

Simple Substances. The names of such elementary substances as had long been known, remain unaltered, as of gold, iron, etc. Those which have been discovered within the period of modern chemistry, have received names expressive of some obvious property; thus, the name oxygen signifies a generator of acids; iodine, violet-colored, from the beautiful color of its vapor; chlorine, green, from the color of the gas. The following are the names of the simple substances with their symbols annexed:

Oxygen,	O.	Cadmium,	Cd.
Chlorine,	Cl.	Tin (Stannum),	Sn.
Iodine,	I.	Cobalt,	Co.
Bromine,	Br.	Nickel,	Ni.
Fluorine,	F.	Arsenic,	As.
Hydrogen,	H.	Chromium,	Cr.
Nitrogen,	N.	Vanadium,	V.
Carbon,	C.	Molybdenum,	Mo.
Sulphur,	S.	Tungsten (Wolfram),	W.
Phosphorus,	P.	Columbium (Tantalum),	Ta.
Boron,	B.	Antimony (Stibium),	Sb.
Silicon,	Si.	Uranium,	U.
Selenium,	Se.	Cerium,	Ce.
Potassium (Kalium),	K.	Bismuth,	Bi.
Sodium (Natrium),	Na.	Titanium,	Ti.
Lithium,	L.	Tellurium,	Te.
Barium,	Ba.	Copper (Cuprum),	Cu.
Strontium,	Sr.	Lead (Plumbum),	Pb.
Calcium,	Ca.	Mercury (Hydrargyrum),	Hg.
Magnesium,	Mg.	Silver (Argentum),	Ag.
Aluminium,	Al.	Gold (Aurum),	Au.
Glucinum,	G.	Platinum,	Pl.
Yttrium,	Y.	Palladium,	Pd.
Thorium,	Th.	Rhodium,	R.
Zirconium,	Zr.	Osmium,	Os.
Manganese,	Mn.	Iridium,	Ir.
Iron (Ferrum),	Fe.	Latanium.	
Zinc,	Zn.		

Acid Compounds. The names of acid compounds have a peculiar construction. All the acids formed by combination of oxygen with other substances, including a great majority of the whole number, take the name of the other substance, (which is called the *base*,) changing its termination. If there be two oxygen acids formed with the same substance, the stronger, which contains more oxygen, takes the termination *ic*, and the weaker, *ous*. In the case of more numerous acid compounds, the prefix *hypo*, signifies inferiority, as in the following of oxygen with sulphur, beginning with the stronger, and proceeding to the weaker:

Sulphuric acid,	Sulphurous acid,
Hyposulphuric acid,	Hyposulphurous acid.

Sometimes the prefix *per* is used to indicate an additional, but indefinite quantity of oxygen. Thus, *perchloric acid* contains more oxygen than *chloric acid.*

Acids, which do not contain oxygen, receive names which are compounded of the names of their constituents, the first enunciated terminating in *o*, and the last in *ic;* as chloro-carbonic acid. Often the first is shortened, as fluo-boric instead of fluro-boric; this is the case with the hydrogen acids; as hydrochloric acid, hydrosulphuric acid.

Primary Compounds which are not acids. In such compounds the names are composed of the names of their constituents. In the compounds of oxygen, chlorine, iodine, bromine, and fluorine, with other substances, they are first enunciated and receive the termination *ide;* as oxide of iron, chloride of iron, iodide of mercury, bromide of carbon, fluoride of zinc. In their compounds with each other, the order of enunciation is not essential, although it is commonly that, in which they are above mentioned; thus we may say chloride of bromine, or bromide of chlorine, but the former is more common.

Compounds of the other non-metallic substances with each other and with the metals, receive names of similar construction, except that the termination *uret* takes the place of *ide;* as carburet of iron, bicarburet of hydrogen, sulphuret of arsenic.

In many cases, one substance unites with another in several proportions, and the compounds are designated by numeral prefixes, *proto* the first, *bi* (formerly *deuto* was used) the second, *ter* the third, *quadro* the fourth, etc., and *per* the highest degree, but indefinite; *sesqui* signifies one and a half. If, however, the last terminated substance or base, be in two or more proportions, the dividing prefixes *di*, *tri*, etc. are used; *subsequi* indicates one and a half of the base.

The following table exhibits all the cases of the use of numeral prefixes:

Triphosphuret of Copper	= 1	equiv.	Phosphorus	and 3	equiv.	Copper.
Dinoxide of Copper	= 1	“	Oxygen	and 2	“	Copper.
Subsesquiphosphuret of Copper	= 1	“	Phosphorus	and 1 1-2		Copper.
Protoxide of Copper	= 1	“	Oxygen	and 1	“	Copper.
Sesquioxide of Manganese	= 1 1-2		Oxygen	and 1	“	Manganese.
Binoxide of Manganese	= 2	“	Oxygen	and 1	“	Manganese.
Teriodide of Nitrogen	= 3	“	Iodine	and 1	“	Nitrogen.
Quadrochloride of Nitrogen,	= 4	“	Chlorine	and 1	“	Nitrogen.

Peroxide of Iron = Iron oxidated in the highest degree.

Many metals, whose names terminate in *um*, merely change *ium* or *um* into *a* to indicate the state of protoxide. Thus potassa = protoxide of potassium, lithia = protoxide of lithium, etc. The protoxide of calcium has long been known by the name of lime.

Alloys, or compounds of metals with each other, not being yet reduced to the laws of definite proportions, have no systematic names.

Some primary compounds, whose combinations are analogous to those of simple substances, receive simple names, which in composition receive the termination *uret*, and follow the rules above given. These are *ammonia* and *cyanogen*. Another primary compound, *water*, forms compounds which are called *hydrates*, as *hydrate of lime*.

Secondary compounds, or *salts*. These are formed by the combination of acids with other primary compounds, which are called, in reference to them, *bases*. The name of a salt is composed of the names of the acid and base. If the name of the acid have a termination *ic*, it is changed into *ate*; *ous* is changed into *ite*. Numeral prefixes are used according to the rules which have been given, as in the following examples.

Dinitrate of the protoxide of lead = 1 eq. Nitric acid and 2 eq. protoxide of lead.
Protonitrate of mercury = 1 " " and 1 " " of mercury.
Sesquisulphate of potassa = 1 1-2 Sulphuric acid & 1 " potassa.
Bisulphate of peroxide of Mercury = 2 eq. " and 1 " perox. of mercury.
Tersulphate of alumina = 3 " " and 1 " alumina.

As the acids never unite with the metals directly, but generally with their oxides, and sometimes other compounds, in the case of the oxides, the name is abbreviated: thus, by protonitrate of mercury, is always understood protonitrate of the protoxide of mercury. Also, the prefix proto is often understood, and we say, nitrate of mercury.

There are many secondary compounds, little known however except to the chemist, called sulphur salts, and haloid salts, whose nomenclature follows the rules of primary compounds which are not acid.

Notation.

Notwithstanding the great advantages of the chemical nomenclature, a much greater help is given to the student in the notation. By this, as in Algebra, long and intricate processes are exhibited to the eye at a glance, and the relations of the constituents in complicated compounds easily comprehended. Each element is represented by a symbol consisting of its initial, or in the case of two or more which have the same initial, of the initial and one of the following letters, as on page 116, where the symbols of all the elementary substances are given. In the case of potassium, sodium, tin, iron, and several others, the symbols are derived from the Latin names.

The symbols of compounds are composed of the symbols of their constituents, algebraically connected; as $Fe+Cl$, chloride of iron. In primary compounds the sign $+$ is often omitted. Coefficients are used to show the number of equivalents, as $N+4Cl$, quadrochloride of nitrogen; or if several symbols are written together without the sign $+$, an index is substituted for the coefficient, because the coefficient multiplies all which come between it and the next sign. Thus the symbol of the substance last mentioned may be written, NCl^4.

Cyanogen, ammonia, and water, although compounds, have simple symbols like the elements; thus we have Cy, Am, and Aq (*Aqua*), instead of NC^2, H^3N, and HO.

The symbols of oxygen and sulphur are abbreviated. The symbols for the compounds of oxygen, are written thus: $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ for $N+5O$, $\overset{\cdot\cdot\cdot\cdot}{N}$ for $N+4O$, $\overset{\cdot\cdot\cdot}{N}$ for $N+3O$, etc., each dot indicating an equivalent of oxygen. A comma is used in the same manner for the compounds of sulphur, thus $\overset{,}{P}$ for PS. In place of the coefficient 2, a dash is often drawn through or beneath the symbol. This is very convenient in the case of half equivalents; as $\underline{\overset{\cdot\cdot\cdot}{Mn}}$, signifying $2Mn+3O$, that is $Mn+1\frac{1}{2}O$, sesquioxide of manganese. In compounds of complicated constitution, it is often necessary to multiply several terms by one number, or to connect them as a whole to another term. This is done as in algebra, by the use of vincula or parentheses; thus $(\dot{K}+2\dddot{S})+Aq$, shows that Aq is combined with $\dot{K}+2\dddot{S}$, as with one substance; but if the parentheses were omitted, thus $\dot{K}+2\dddot{S}+Aq$, the symbol would indicate a combination of three distinct substances, each one with the other. Also in $2(\dot{K}+2\dddot{S})$, the first coefficient belongs to what is within the parentheses as to one substance.

If the student will, for practice, explain the constitution and give the names of the compounds in the annexed table, he will become familiar with the rules of nomenclature and notation.

The following table contains the names, equivalents, and symbols of the thirteen non-metallic elements, and the symbols of their compounds with each other, in the order in which they are described:

Oxygen,	equiv.	8	symbol	O.
Chlorine,	“	35.42	“	Cl, $Cl+O$, $Cl+4O$, $Cl+5O$, $Cl+7O$.
Iodine,	“	126.3	“	I, $I+5O$, $I+7O$, $3Cl+I$.
Bromine,	“	78	“	Br, $Br+5O$ or BrO^5.
Fluorine,	“	18.68	“	F.
Hydrogen,	“	1	“	H, $H+O$ or $\dot{H}$, $H+2O$ or $\ddot{H}$, $H+Cl$, $H+I$, $H+Br$, $H+F$ or HF.
Nitrogen,	“	14.15	“	N, NO or $\dot{N}$, NO^2 or $\ddot{N}$, NO^3 or $\dddot{N}$, NO^4 or $\ddddot{N}$, NO^5 or $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, NCl^4, NI^3, NH^3.
Carbon,	“	6.12	“	C, $\dot{C}$, $\ddot{C}$, $C+Cl$, C^4Cl^5, C^2Cl, CCl^3, $\dot{C}+Cl$, CH^2, C^2H^2, C^4H^4, C^6H^3, C^6H^5, $C^{10}H^4$, $C^{15}H^6$, $C^{10}H^8$, HCy, CyO, $Cy^3O^6H^3$, $CyCl$, $CyCl^2$, $HCyS^2$, CyS^2, H^2CyS^2.
Sulphur,	“	16.1	“	S, SO^2, SO^3, $\underline{SO^2}$, $\underline{SO^5}$, S^2Cl, SCl, HS, HS^2, CS^2.
Phosphorus,	“	15.7	“	P, P^2O, P^3O, P^2O^3, P^2O^5, P^2Cl^3, P^2Cl^5, PI, P^2I^3, PBr, P^2Br^5, H^3P^2.
Boron,	“	10.9	“	B, $B+3O$, $B+3Cl$, $B+3F$.
Selenium,	“	39.6	“	Se, $Se+O$ or $\dot{Se}$. $Se+2O$ or $\ddot{Se}$, $Se+3O$ or $\dddot{Se}$.
Silicon,	“	22.5	“	Si, $Si+O$, $SiCl$, $SiBr$, SiS, SiF.

CHAPTER I.

CHEMICAL SUBSTANCES.

These substances will be arranged in three classes of non-metallic elements, and their primary compounds, with each other; metals with their primary compounds, and secondary compounds, or salts.

Class I. *Non-metallic elements and their primary compounds with each other.*

Sect. 1. Oxygen.

$$\text{Symb. O. Equiv.}\begin{cases}\text{by vol. } 50.\\ \text{`` wgt. } 8.\end{cases}\qquad \text{Sp. gr.}\begin{cases}1.1024 \text{ Air } = 1.\\ 16. \quad \text{Hyd.} = 1.\end{cases}$$

History. Oxygen was discovered by Dr. Priestly of England, August, 1774, by exposing the red oxide of mercury to the solar focus. It was also discovered by Scheele, a Swedish chemist, in 1795, and the same year by Lavoisier of Paris, neither being acquainted with the discovery by the others. The honor of the discovery, as is usual in such cases, is ascribed to Priestly, who called it *dephlogisticated air*; Scheele gave it the name of *empyreal air*, Condorcet, *vital air*, and Lavoisier, *oxygen*. This name was suggested from the belief that it was the only acidifying principle in nature. It is derived from two Greek words,* signifying a generator of acids. It has since been found, however, that although present in most acids, it is not the only substance capable of forming acid compounds. But as a great majority of acids are oxygen acids, the name is not inappropriate.

Natural History. Oxygen is the most abundant substance known. It forms $\frac{1}{5}$ of the atmosphere, $\frac{8}{9}$ part of water. By far the greater part of the solid crust of the earth is composed of oxydized substances, and it will not be far from the truth, if

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* ὀξυς and γεννάω.

Pneumatic cistern

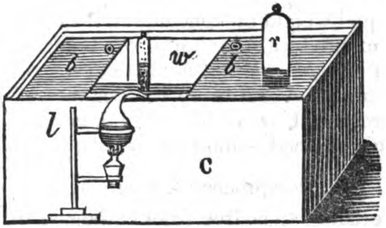
we estimate oxygen to constitute $\frac{2}{5}$ of all the matter with which we are acquainted.*

Processes. Oxygen can easily be obtained from the oxides of metals, and from some of the salts. The oxides of manganese and of lead, and the chlorate of potassa, are most commonly used.

The separation is effected by exposing these substances to a red heat, in an iron retort, connected by a pipe with the pneumatic cistern.

For the collection of gases which are not absorbed by water, the ***Pneumatic Cistern*** is generally employed.

Fig. 47.



It consists of an oblong box C (fig. 47.), made water tight; *bb* two shelves to support receivers, as *r*; *w* a well filled with water, across which a board is placed, also to support receivers, with small holes to let the gas through as it comes from the retort, which is placed over the side of the box. The shelves *bb* may be made for *gasometers*, or *gas-holders*, and in that case they are boxes open at the bottom of the cistern, with stop-cocks passing through one corner in the top of each. These are made air tight by a lining of sheet lead. When they are filled with water, the gas is introduced by means of a lead pipe through an aperture in the side of each, near the bottom; as it rises up it displaces the water; *l* is a lamp-stand and retort, as it is connected with the cistern.†

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* If we suppose the sun and planets with the stellary systems to be composed of matter similar to our earth, the quantity of oxygen which actually exists, must be immeasurably great.

† The cistern may be made of wood, or copper which is the best, of any convenient dimensions. One five feet long, twenty inches wide and twenty inches in height is sufficiently large for common purposes.

Theory. To understand the theory of the process by manganese, it is necessary to notice the composition of its three oxides.

	Manganese.	*Oxygen.*	
Protoxide,	27.7 or 1 equiv.	+ 8 or 1 equiv.	= 35.7
Sesquioxide,	27.7 "	+ 12 or 1½ "	= 39.7
Peroxide,	27.7 "	+ 16 or 2 "	= 43.7

The oxygen may be separated from the binoxide in two ways.

1. By simply exposing it to a red heat. In this case the binoxide parts with ½ equiv. of oxygen, and is converted into sesquioxide. 1 oz. of manganese will yield 128 cubic inches of oxygen.

2. By putting it in fine powder into a glass flask with an equal weight of concentrated sulphuric acid, and heating the mixture by a spirit lamp, the manganese parts with one equiv. of oxygen, and the sulphate of the protoxide of manganese remains. About twice the quantity of gas is obtained by this process, 1 oz. yielding 256 cubic inches of gas. But the former method is most convenient in practice.

For these processes, the manganese should be previously ascertained to be free from carbonate of lime, which yields carcarbonic acid gas on being heated.* Oxygen obtained in this way is not quite pure, but is sufficiently good for all purposes of experiment. The gas obtained from chlorate of potassa is much purer, but more expensive.

It may be easily obtained by subjecting the salt to a dull red heat in a green or white glass flask, made without lead, or in an iron retort. It first becomes liquid, and is then resolved into oxygen and chloride of potassium.

The chlorate of potassa is composed of chloric acid and potassa, and the theory of the process may be thus explained: $KO+CLO^5$, are resolved into $K+CL$, which remains in the flask, and 6 equiv. of oxygen, which are collected over the cistern. One ounce of chlorate of potassa will give about 640 cubic inches of oxygen.

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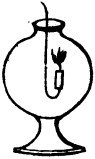
* It may be freed from carbonate of lime by washing it in dilute hydrochloric acid.

Physical Properties. Oxygen is transparent, colorless, tasteless, and inodorous. In the simple state, it always exists in the form of a gas. It cannot be condensed to a liquid or a solid, by pressure or cold. It refracts light, the least of all other substances; is a non-conductor of electricity; is the only substance whose electric state is *absolutely negative;* and of course it always goes to the *positive pole* in the galvanic circuit. Its specific gravity is 1.1026; consequently, 100 cubic inches, when the thermometer is at 60° Far. and the barometer at 30 inches, will weigh 34.1872 grains. It is a little heavier than atmospheric air.

Chemical Properties. Oxygen possesses more extensive powers of combination than any other substance. It may be made to combine with all the simple substances. For acids, and alkalies it has little affinity, because these substances have already received their proportion of it. Some of its combinations with the metals, and with combustibles, are very energetic.

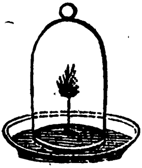
Fig. 48.



Exp. Let down a pendant candle into a jar of the gas (fig. 48.), and it will burn with great brilliancy.

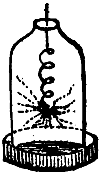
Exp. Blow out a candle leaving a red wick, and let it down into a jar of the gas, when it will be relighted with a slight explosion. This process may be repeated several times in rapid succession with the same jar of gas.

Fig. 49.



Exp. If a bit of lighted phosphorus, in a capsule, be immersed in this gas (fig. 49.), it will burn with great energy, and intense brilliancy. Substitute for the phosphorus a small ball formed of turnings of zinc, in which a small bit of phosphorus is enclosed, and set fire to the phosphorus as before. The zinc will be inflamed, and burn with a beautiful white light. Metallic arsenic, moistened with spirits of turpentine, and various other metals, in fine powder, may be burned in a similar manner. Homberg's pyrophorus flashes spontaneously like inflamed gun-powder.

Fig. 50.



Exp. If iron wire, with a small lighted match attached to one end, be let down into a tubulated bell glass of oxygen, it will burn rapidly, and if a watch-spring be used (fig. 50.), the bell glass will be filled with beautiful star-shaped scintillations.

Exp. Or, let a stream of oxygen upon ignited charcoal, upon which is placed the end of a watch spring; it will burn with great brilliancy, and throw out immense numbers of the star-shaped scintillations.

In these experiments, the oxygen combines with the combustible substance, and forms a compound, which being now oxidized, is incapable of further combustion. In case of the iron, an oxide is formed, the weight of which is exactly equal to that of the iron and the oxygen together.*

The combination of oxygen with other substances, is called *oxygenation*, and if the compound be an oxide, *oxidation.*† Oxygen is slightly absorbed by several substances; 100 cub. inches of water absorb three or four cub. inches of the gas.

The relation of oxygen to animal life is very intimate and important. It is the only substance which will for any length of time support respiration. No animal can live without it. If confined in gases destitute of oxygen, death is the certain consequence. A few years since, 148 persons were confined in a prison called 'Black Hole' in Calcutta for a night, and although there were two windows open in the west end of the building, only twenty-three were found alive in the morning.

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* In the case of combustion, the common opinion that the matter is destroyed, is erroneous. If the products are collected, they will be found equal in weight to the substances burned. It is a universal law that no particle of matter is annihilated.

† It has been customary with many to call oxygen, and some other kindred substances, "supporters of combustion," while the substance with which they combine are called combustibles. But the supporter of combustion and the combustibles are alike essential to the combustion, and both are consumed in the process. Indeed, if the latter be in excess, a portion of it will remain, while the former will be entirely consumed. Generally, the supporter of combustion, as it is called, is a gas which envelopes the combustible; but there is no scientific distinction.

Pure oxygen is generally destructive to animal life. The animal confined in it lives too fast; breathing becomes difficult, and if it remain for any time, death will ensue. If the quantity be small, it will support life longer than the same quantity of common air. A bird will live five or six times as long in a few gallons of oxygen as in the same quantity of confined air. In order to its most salutary effects, it should be diluted with nitrogen, as we find it in the atmosphere. The Creator has, in this respect, adapted it to the support of life, as anything which destroys the relation thus established, renders it deleterious to the animal constitution.

Uses. Oxygen has been used with good results in certain diseases, such as paralysis of the thorax, and general debility. Its effect upon the blood is to change it from dark red to a bright vermillion.

SECT. 2. CHLORINE.

$$\text{Symb. Cl. Equiv.}\left\{\begin{array}{l}\text{By vol. }100.\\ \text{,, wgt. }35.42.\end{array}\right. \qquad \text{Sp. Gr.}\left\{\begin{array}{l}2.47\text{ Air }=1.\\ 35.42\text{ Hyd. }=1.\end{array}\right.$$

History. Chlorine was discovered by Scheele in 1774, and described under the name of *dephlogisticated marine acid.* The French chemists called it *oxygenized muriatic acid*, afterwards contracted to *oxy-muriatic acid.* This name implied a theory of its composition, suggested by Berthollet, that it was a compound of muriatic acid and oxygen. Gay Lussac and Thenard, in 1809, first suggested that it might be a simple substance. Sir H. Davy, after subjecting it to the most powerful decomposing agents, without in the least affecting its character, denied its compound nature, and maintained that, according to the true logic of chemistry, it should be regarded as a simple body. The views of Davy were for a long time combatted. Drs. Murray and Thompson in England, and Berthollet, Gay Lussac, and Thenard in France, engaged with great warmth in the controversy. But the name *Chlorine*, suggested by Davy from a Greek word* signifying *green*, not implying any theory as to its nature, came gradually into use, and the contest subsided. It is now universally regarded as a simple substance.

The introduction of Chlorine into the class of simple bodies changed entirely the views of chemists relative to the theory of combustion. Previous to the discovery of oxygen, the Stahlian theory of combustion was generally adopted. According to this theory, combustion was the escape from combustibles of a certain principle called *phlogiston*, which pervaded most bodies. Soon after the discovery of oxygen, Lavoisier made an attack upon the phlogistic, or Stahlian theory, and proved that combustion was produced by the union of *oxygen* with some combustible body. But when the properties of chlorine were investigated, and it was viewed as a simple substance, it was found to produce all the phenomena of combustion. Hence the theory of Lavoisier, that combustion was owing to the union of oxygen with a combustible was extended, and the phenomena of combustion are not referred to any more specific cause than *intensity of chemical action.*

Natural History. Chlorine is one of the constituents of common salt, and therefore exists in the ocean in large quantity. Other compounds in the mineral kingdom are numerous.

Process. It may be obtained in the form of a gas, by the action of hydrochloric acid upon the binoxide of manganese.

Take the latter, finely powdered, in a retort, and pour on twice its weight of concentrated hydrochloric acid. Collect the gas over the cistern in inverted bottles containing warm water, or more conveniently, over a small cistern of warm water. The water should be raised to 70° or 80° Far., as cold water rapidly absorbs the gas. Apply a moderate heat, and when the bottles are filled, they should be stopped with ground glass stoppers smeared with tallow.

Theory. In this process, the binoxide of manganese is decomposed into protoxide, and oxygen. A part of the acid combines with the protoxide, and another is decomposed, its hydrogen uniting with the oxygen and forming water, and the chlorine is set free. In other words, the MnO^2 and HCl are converted into $MnO+HCl$, and HO which remain in the retort, and Cl which comes over.

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* χλωρος.

The cheapest mode of obtaining chlorine is the following:

Put eight ounces of common salt with three ounces of pulverized peroxide of manganese, and five ounces of sulphuric acid diluted with equal weights of water, into a Florence flask or retort, and apply heat as before. The MnO^2, $Na+Cl$, and $2SO^3$ are converted into $MnO+SO^3$, $NaO+SO^3$, and Cl.

Physical properties. Chlorine gas is of a yellowish green color; has an astringent taste, and a disagreeable odor; is a non-conductor of electricity, and goes to the positive pole in the galvanic circuit. By the pressure of four atmospheres, or 60 lbs. to the square inch, it is condensed into a yellow liquid, and into a solid by the reduction of the temperature below 32°.*

Chemical properties. Chlorine unites with many substances with great energy, producing combustion; but its range of affinity is more limited than that of oxygen.

Exp. If a small lighted taper be immersed in a jar of the gas, the taper will burn for a short time with a small red flame, evolving large quantities of smoke.

Exp. Into a tall glass vessel, filled with chlorine, throw finely pulverized antimony, which will burn as it falls through the gas.

Exp. A rag wet with oil of turpentine, will instantly be inflamed, when immersed in the gas.

Several other metals and combustibles combine with chlorine with such energy, as to exhibit the phenomena of combustion.

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* Mr. Faraday succeeded in condensing it in a bent tube, sealed hermetically. The pressure is produced by the accumulation of the gas evolved by the affinities between the materials in the short end of the tube. The experiment is attended with the hazard of breaking the tube, and should not be attempted, unless the hands and face are protected.

Chlorine is readily absorbed by water. Recently boiled water when cold absorbs twice its bulk, but gives it off when heated.

Exp. Into a jar furnished with a well-fitted glass stopper, and filled with cold water, let up chlorine gas enough to displace half the water; stop it tight, and shake it, and most of the gas will be absorbed by the water. Open the jar under more cold water, which will rush into it to fill the vacuum occasioned by the absorption of the chlorine; then repeat the process once or twice, and the water will be saturated with chlorine, and possess most of its properties. If the water in this experiment be at the temperature of 32° Far., the chlorine will form a definite solid compound with it, in yellow crystals, which will be seen on the sides of the jar.

Chlorine forms with hydrogen, if the vapor of water be present, a mixture which explodes violently when exposed to the direct rays of the sun, or even in a bright day without such exposure.

This gas possesses remarkable *bleaching properties.*

Exp. Immerse in the gas strips of calico, flowers, etc. and they will be bleached in a short time; or the saturated water may be used.

Exp. Pour some of the saturated water into a small quantity of ink, and the color will be discharged; or put into it some writing, which will become invisible, but will be restored if immersed in a solution of prussiate of potassa. Printers' ink will not be affected, and hence chlorine water may be used for removing blots from books.

Chlorine is not an acid; for it does not redden vegetable purples, and it combines directly in definite proportions with the metals, which is not true of any acid. It is not alkaline.

Chlorine is very destructive to animal life. A few bubbles of gas, in the atmosphere of a room, will bring on coughing. Half a gill undiluted in the lungs would cause death. If diluted largely with air, it irritates the throat and lungs, and if pure, destroys their texture. Pelletier is said to have fallen a victim to its effects. The antidote is ammonia.

Uses. *The bleaching properties* of chlorine are turned to great account in the art of bleaching. Both the gas and the water saturated with it were employed as early as 1784–5 for bleaching cloths—but it proved injurious to the workmen. In 1789, the gas was condensed in a solution of pearlashes, and went by the name of "*Liquid javelle.*" But this substance soon gave place to Mr. Tennant's preparation of the chloride of lime, in 1798. Since that period, most of the bleaching of cotton and linen goods, has been effected by this substance. The articles to be bleached are first steeped in hot water, boiled in a weak alkali, and then immersed in a solution of the chloride of lime. They are next taken out, and washed in water,—sometimes diluted sulphuric acid is applied to increase their whiteness,—and finally, they are boiled in pearlashes and soap, to render them free from the odor of chlorine. Chloride of soda, magnesia, and potassa are sometimes used, but they are more expensive.*

Theory. The theory of this process, perhaps, would be better understood after learning the composition of water, but it can be given here with a little explanation. Water is necessary to the bleaching effects of chlorine. It is composed of oxygen and hydrogen. The chlorine having a strong affinity for the hydrogen, decomposes the water, and leaves the oxygen to combine with the coloring matter. The coloring matter may also contain hydrogen, and thus be directly decomposed by the chlorine. The coloring matter is rendered soluble by combination with oxygen, and is removed by the alkali. The process of bleaching by chlorine, is but one out of many useful contributions of science to art.

Another use of chlorine arises from its *disinfecting agen-*

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* The advantages of this mode of bleaching, over the one formerly employed, are very great. By the old method, large fields in the vicinity of every manufactory were devoted to the purpose of spreading the cloths. These fields are now devoted to agriculture. It required also several weeks and even months to complete a process, which may now be performed in as many days. In the former case, they were dependent upon the light of the sun and fair weather; in the latter, they are independent of the weather, and of the seasons of the year.

cy. It seizes hold of every species of animal and vegetable effluvia, and decomposes them. Hence its utility in contagious diseases. The chloride of lime is used for this purpose. Moisten the dry chloride with water, and place it in the infected apartment, which will soon be purified. It is thus very useful for dissecting-rooms, for cleaning drains, sewers, vessels, and even the atmosphere, when charged with miasma. Its use in medicine is mostly confined to the purification of apartments of the sick. The chloride of soda is, however, used in certain cases of inflammation, such as ulcers, mortification, and cutaneous diseases. It is also used as a wash for the teeth.*

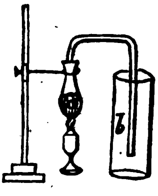
Chlorine and Oxygen.

The compounds of chlorine and oxygen are held together by very feeble affinities, and *are never met with in nature.* They cannot be made to combine directly, unless they are in the *nascent* state, that is, at the instant of their formation.

Hypochlorous acid. Symb. $Cl+O$ or ClO. Equiv. $35.42+8=43.42$. Sp. gr. 3.0212. It was discovered by H. Davy in 1811, and called *euchlorine* from its being of a brighter color than chlorine.

Preparation. Put two parts of the chlorate of potassa and one of hydrochloric acid into a retort, and apply the heat of water under 200° Far. Collect over mercury, or it may be more conveniently prepared for experiment by placing the materials in a flask *a* (fig. 51), connected by a glass tube, bent twice at right angles, with a tall receiver *b*. Apply heat as before; the gas being heavier than the air, will displace it, and fill the receiver.

Fig. 51.



Theory. The hydrochloric acid, and the chloric acid in the chlorate of potassa mutually decompose each other, and the results are water, and the hypochlorous acid. 2 equiv. HCl, and one of $KO+ClO^5$, are converted into KO, 2 Aq., and $3ClO$.

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* So many and great are the advantages of cleanliness and pure air, that *chloride of lime* should be kept in every family, especially in cities and large towns; but an apartment in which it has been used, should be thoroughly ventilated before it is again occupied, or weak lungs may be seriously injured.

If it be collected over mercury, the chlorine unites with the mercury, and the acid remains in a pure state.

Properties. Greenish yellow color, more brilliant than chlorine; odor like burned sugar; absorbed rapidly by water, and gives to it an orange color; bleaches vegetable substances; gives vegetable blues a red tint before destroying them; does not unite with alkalies, and hence has been considered as a *protoxide of chlorine;* highly explosive, the heat of the hand being sufficient often to explode it. Many substances take fire in it spontaneously.

Exp. A rag dipped in spirits of turpentine will kindle in it with a slight explosion.

Exp. Phosphorus explodes in it spontaneously. Fifty measures of this gas, and eighty of hydrogen, form an explosive mixture.

Chlorous acid. Symb. $Cl+4O$, or ClO^4. Equiv. $35.42+32=67.42$. Sp. gr. 2.3374. Discovered by Davy in 1815, and soon after by Count Stadion of Vienna, and has been heretofore described as *peroxide of chlorine.*

Preparation. Make a paste of strong sulphuric acid and chlorate of potassa; put it into a retort, and apply the heat of warm water under 212° Far. Collect over mercury, or as in fig. 51.

Properties. Color, bright orange green, richer than the preceding compound; aromatic odor; is absorbed rapidly by water, and gives it its peculiar color; bleaches powerfully, and is more explosive than hypochlorous acid.

Exp. Put a bit of phosphorus into a wine glass filled with the gas. It will instantly ignite with a slight explosion.

Chloric acid. Symb. $Cl+5O$, or ClO^5. Equiv. $35.42+40=75.42$. It was first noticed by Mr. Chenevix, and obtained in a separate state by Gay Lussac.

Preparation. To a dilute solution of chlorate of baryta, add dilute sulphuric acid sufficient to combine with the baryta. Pure chloric acid will remain after the baryta subsides.

Theory. The sulphuric acid has a stronger affinity for baryta than the chloric acid, with which it has combined, decomposes it, and leaves the chloric acid.

Properties. Sour to the taste; reddens vegetable blue colors, but possesses no bleaching properties, by which it is distinguished from the preceding compounds. It may be concentrated by gentle heat into an oily liquid of a yellow tint, emitting the odor of nitric acid. In this state, it sets fire to paper and dry organic matter, and converts alcohol into acetic acid.

Perchloric acid. Symb. $Cl+7O$ or ClO^7. Equiv. $35.42+56=91.42$. Sp. gr. 1.65, water = 1. It was first described by Count Stadion of Vienna.

It may be obtained by heating a mixture of 1 part of water, 3 of sulphuric acid, and 5 of perchlorate of potassa. At a temperature of 284°, white vapors arise in the receiver which are soon condensed into a colorless liquid. By admixture with sulphuric acid, and distillation, it crystallizes in elongated prisms.

It is a very stable compound—absorbs moisture from the air powerfully, and boils at 392° Far. When thrown into water, it hisses like red hot iron.

SECT. 3. IODINE.

Symb. I. Equiv. { By vol. 100. / " wgt. 126.3. Sp. Gr. { 4.948 Water = 1. / 8.702 Air = 1.

History. Iodine was discovered in 1812, by a manufacturer of salt-petre, M. Courtois of Paris. The substance in which it was first noticed, was the residual liquor after the preparation of soda from the ashes of sea-weeds. This dark colored liquor possessed the peculiar property of powerfully corroding metallic vessels; on the application of sulphuric acid, he noticed that it threw down a dark colored substance, which was converted into a violet-colored vapor on the application of heat. This attracted his attention, and he gave some of it to M. Clement, who in 1813, described it as a new body. Gay Lussac and Davy soon after proved it to be a simple non-metallic substance, analogous to chlorine. The name Iodine is derived from a Greek word,* significant of the beautiful violet-color of its vapor.

Natural History. Iodine exists in nature but in small quantities. It is found mostly in sea-weeds, in sponges, in the oyster and some other mollusca, in many salt and mineral springs, both in Europe and America. Vanquelin found it in combination with silver; marine animals and plants derive it from sea-water. Most of the iodine of commerce is obtained from the impure carbonate of soda, called *kelp*. This is nothing but the ashes of sea-weed, great quantities of which are prepared on the shores of Scotland. Iodine exists in combination with sodium and potassium in the liquor which is left after the carbonate of soda crystallizes.

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* Ιώδης.

Process. Iodine may be obtained by lixiviating the powdered kelp in cold water. Evaporate the lye till the carbonate of soda crystallizes; take the residual liquor, and evaporate it to dryness; pour on to this ½ its weight of sulphuric acid; it may then be put into a common retort, to which is attached a globe receiver, and the retort heated; violet-colored fumes will soon arise and be condensed into the receiver, in the form of opaque crystals, of a metallic lustre. These are to be washed in water, and dried on a filter of unglazed paper.

Physical Properties. Iodine, at the common temperature, is a soft, pliable, opaque solid, of a blueish black color, and of a metallic lustre. It is generally found in small crystalline scales, resembling micaceous iron ore, or the scales from a smith's forge. But it may be made to crystallize in large rhomboidal plates, whose primary form is a rhombic octohedron, by saturating hot alcohol, or hydriodic acid with it, and evaporating in the open air. It is very acrid to the taste, and has the odor of chlorine. Like O and Cl, it is a non-conductor of electricity, and goes to the positive pole in the galvanic circuit. It acts as a powerful poison to the animal system. Fuses at 225°, and boils at 347° Far. If water be present, it volatilizes at the common temperature, and sublimes rapidly under 212°. The rich violet vapor of iodine is remarkably dense, more than eight times as heavy as air. One hundred cubic inches would weigh 269.8638 grs.

Exp. This vapor may be shown by putting a few grains of the iodine into a glass flask, and applying a gentle heat.

Chemical properties. Iodine has an extensive range of affinity. Like chlorine it destroys vegetable colors, though in a less degree—and like oxygen, and chlorine, it unites directly with the metals and with non-metallic combustibles with great energy.

Exp. Drop a bit of phosphorus upon a few grains of iodine, contained in a wine-glass, and it will be instantly inflamed.

The compounds thus formed resemble those of oxygen and chlorine. It has little affinity for metallic oxides. It is not inflammable, but a supporter of combustion. The imponderables have no effect to change its character, and hence it is regarded as a simple body. It is largely soluble in alcohol, and but sparingly soluble in water, requiring seven thousand times its weight of water for solution.

Tests. Starch is a very delicate *test* of iodine. It gives to the solution a deep blue color. A liquid containing $\frac{1}{450000}$ part of its weight of iodine, receives a blue tinge from a solution of starch.

Iodine is sometimes adulterated with black lead. This may be detached by dissolving it in alcohol, when the lead will not be held in solution.

Uses. Used in medicine in the form of a hydriodate of potassa, for certain glandular diseases. The goitre is a kind of wen growing from the neck, which is very common in Switzerland, in the treatment of which, iodine has been of great service.

Its vapor is irritating to the lungs, and produces copious secretions in the eyes and nostrils.

Iodine forms with oxygen three, perhaps four compounds:

$$\left.\begin{array}{l}\text{1. Oxide of Iodine,}\\ \text{2. Iodous acid,}\end{array}\right\}\text{Composition unknown.}$$

3. Iodic acid, 1 eq. I, $126.3+5$ eq. O, $40=166.3$ eq. Symb. $1+5O$ or IO^5.

4. Periodic acid, 1 eq. I, $126.3+7$ eq. O, $56=182.3$. Symb. $I+7O$, or IO^7.

The first two compounds, oxide of iodine and iodous acid, are yet doubtful. The first is described by M. Sementini of Naples, and the second by Mitscherlich. The oxide is a yellow solid, and the acid a similar liquid, but their properties have not been examined.

Iodic acid was discovered by Davy and Gay Lussac about the same time. Davy who first obtained it in a pure state, called it *oxiodine.*

Preparation. When iodine is brought in contact with the hypochlorous acid, two compounds are formed. The one is a volatile orange-colored substance, chloride of iodine, and the other a white solid, which is iodic acid. Apply heat to expel the chloride, and the iodic acid remains in a pure state. (See Turner, for other processes). In this state, it is *anhydrous* iodic acid, that is, destitute of water.

Properties. It exists as a white semi-transparent crystalline solid, of a strong astringent sour taste, and no odor; fuses at 500° Far., and is resolved into oxygen and iodine.

It is soluble in water, with which it combines, and forms *hydrous iodic acid.* Deliquesces in moist air; reddens vegetable blues, and finally destroys them. With charcoal, sulphur, sugar and similar combustibles, it forms detonating mixtures.

Periodic acid was discovered by Ammermuller, and Magnus, and is obtained from the periodate of silver, by adding cold water. It has decided acid properties, and is analogous in composition to perchloric acid.

Chloriodic acid was discovered by Davy and Gay Lussac. It may be formed by the direct union of chlorine and iodine. If the iodine is fully saturated with chlorine, it forms a yellow solid; but if the iodine is in excess, the color is a reddish orange. It is easily fused, and converted into vapor; deliquesces in the air; forms a colorless solution in water; very sour to the taste; reddens vegetable blues, and finally destroys them; does not unite with alkalies, and hence has been considered a chloride of iodine.

Souberaine has lately distinguished a compound of 3 eq. of chlorine, and one of iodine.

SECT. 4. BROMINE.

Symb. Br. Equiv. { By vol. 100. / " wgt. 78.4. Sp. Gr. { 3. Water =1. / 5.4017 Air =1.

History. Bromine was discovered in 1826, by M. Balard, a young French chemist of Montpelier, who named it *muride,* because obtained from the sea; but in order to correspond with chlorine and iodine it was called *bromine,* from a Greek word,* signifying *rank odor.*

Natural History. It exists in nature in very small quantities. It is found in sea-water, and marine plants, combined with sodium and magnesium. It is found in every sea whose waters have been tested for it, and in many mineral and salt springs.

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* *Βρωμος.*

Process. It is obtained by passing a current of chlorine gas through the bittern of sea-water, and agitating the liquor with a portion of sulphuric ether. The ether dissolves the bromine, from which it receives a beautiful hyacinth red tint, and on standing, rises to the surface. Agitate this solution with caustic potassa, and the bromide of potassium, and bromate of potassa will be formed. Evaporate the liquor and the bromide of potassium will be left, from which the bromine may be distilled.

Physical properties. Bromine at the common temperatures is a deep reddish brown-colored liquor, of a disagreeable odor, and caustic taste; and, like oxygen, chlorine and iodine, is a non-conductor of electricity, and a negative electric; boils at 116.5° Far. and congeals at -4° Far. into a brittle solid. It *volatizes* at the common temperature.

Exp. This may be shown by pouring a few drops of the liquid into a glass flask; it will soon be converted into a beautiful vapor, somewhat resembling the vapor of iodine, of great density.

Chemical properties. Its chemical properties are very analogous to those of chlorine and iodine. It readily bleaches litmus paper, and discharges the blue color of indigo. A lighted taper burns for a few moments in the vapor of bromine, with a flame, green at its base, and red at the top, and is then extinguished.

It unites with great energy with many combustibles.

Exp. Pour a few drops of bromine into a strong wine-glass, and then pour upon it tin or antimony, in fine powder, from a glass fastened to the end of a long rod; the metals will be instantly inflamed. If potassium be used, it will cause a violent explosion.

Bromine is soluble in water, alcohol and ether; the latter is the best solvent. With water at 32° Far., it forms a ***hydrate***, in crystals of a fine red color. It gives to a solution of starch an orange color. Chlorine will displace it from all its combinations with hydrogen. It acts powerfully upon the animal system, and is very poisonous; a single drop upon the beak of a bird, destroys it instantly.

Bromic acid, symb. $Br+5O$ or BrO^5, equiv. $78.4+40=118.4$, may be obtained by pouring sulphuric acid upon a dilute solution of bromate of baryta, and evaporating the solution.

Properties. It has scarcely any odor, acrid to the taste, though not corrosive. It first reddens litmus paper, and then destroys the color.

Chloride of bromine may be formed by transmitting a current of chlorine through bromine, and condensing the disengaged vapors by a freezing mixture. It is a volatile liquid, of a reddish yellow color, less brilliant than bromine. Its vapor is a deep yellow, taste very disagreeable, and odor penetrating, causing a discharge of tears from the eyes. Soluble in water which possesses bleaching properties.

Bromides of iodine. Bromine and iodine unite and form two compounds. The ***proto-bromide*** is a solid easily converted by heat into a reddish-brown vapor, which, on cooling, is condensed into crystals of the same color, and of a form resembling fern leaves. By the addition of bromine to these crystals, they are converted into a liquid, resembling a strong solution of iodine and hydriodic acid; but the nature of it is not satisfactorily established.

SECT. 5. FLUORINE.

Symb. F. Equiv. 18.68, eq. vol. 100.

Fluorine is a name applied to a substance which has not as yet been obtained in a simple state. It is inferred from the nature of its compounds to be similar to oxygen, chlorine, bromine and iodine. It has a strong affinity for hydrogen, and the metals.

Natural History. It exists abundantly in nature, in ***fluor-spar*** combined with calcium, ***(fluoride of calcium)***. Baudrimont is said to have obtained it, mixed with hydrofluoric and fluosilicic acid gases, by treating a mixture of fluoride of calcium and peroxide of manganese with strong sulphuric acid. It appears to be a gaseous body, similar to chlorine.

SECT. 6. HYDROGEN.

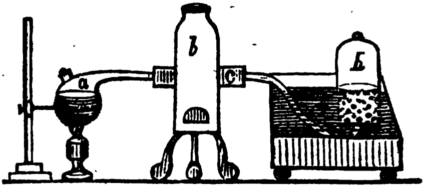
Symb. H. Equiv. { By vol. 100. / " wgt. 1. Sp. Gr. { 0.0689 Air = 1. / 1. Hyd. = 1.

History. The name *hydrogen* is formed from two Greek words,* and means, a generator of water. It was known for many centuries, but was first distinctly described by Mr. Cavendish in 1776. Nine years previous, Dr. Black discovered carbonic acid gas, which was the first gas discovered, except the atmosphere, and hydrogen was the second.

Natural History. Hydrogen is a very abundant substance. It forms $\frac{1}{9}$ part by weight of water. Its chief repository therefore is the ocean; but is widely disseminated through the animal, vegetable and mineral kingdoms. It is the basis of most liquids.

Processes. 1. Water is always employed for obtaining hydrogen. It is composed of oxygen and hydrogen, and the object is to decompose it by presenting some substance, with which the oxygen will combine, and leave the hydrogen to escape in the form of a gas. Iron is such a substance, and will decompose the water slowly at common temperatures; the oxygen combining with it, and forming the well known substance called iron-rust. But if the temperature of the iron be raised to 1000° Far. and the vapor of water passed over it, it will decompose it more rapidly. For this purpose, clean iron turnings, or bright iron wire are placed in the centre of a gun-barrel C (fig. 52.), open at both ends, and passed through a furnace *b*. Into one end the vapor of water is made to pass from the retort *a*, and the other end is connected by a lead pipe with the pneumatic cistern. As the vapor passes over the iron, its oxygen combines with it, and its hydrogen passes over into the receiver *h*.†

Fig. 52.



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* ὕδωρ and γεννάω.

† If the water and the iron are weighed before the experiment, and

2. It is more conveniently obtained, by putting small pieces of zinc,* or iron turnings into a glass, or lead retort, and pouring on one part of sulphuric acid, diluted with four parts by weight of water, and collecting as above.

Theory. In this process the oxygen of the water unites with the zinc, and forms oxide of zinc, which combines with the acid, while the hydrogen of the water escapes. This was formerly supposed to be a case of what was called *disposing affinity*, in which the acid disposed the oxygen and zinc to unite, that it might combine with the compound; for it has no affinity for them separately. This is sufficiently absurd. The process commences with zinc and water alone, without the aid of the acid, and is immediately arrested by the formation of a coat of oxide of zinc, which protects the zinc from the action of the water. The acid dissolves away this coating of oxide as fast as formed, and thus the action of the metal and the water is uninterrupted.

For every nine grains of water which are decomposed, one grain of hydrogen will be set free. Eight grains of oxygen will unite with twenty-eight of iron, forming thirty-six of the protoxide of iron. One oz. of iron will yield 782 cubic inches, and one oz. of zinc 676 cub. in. of hydrogen.

Impurities. The hydrogen, obtained in these processes, is not quite pure. That from the iron contains a volatile oil, produced by the hydrogen and the carbon in the iron; this may be removed, by passing the gas through alcohol. When zinc is employed, (and it is generally preferred,) the impurities result from the sulphur which it generally contains—hydrosulphuric acid is formed, and there are also traces of metallic zinc and carburetted hydrogen. These, except the last, may be removed by passing the hydrogen through pure potassa. When hydrogen of great purity is required, distilled zinc should be used.

Physical properties. Hydrogen gas is colorless, tasteless,

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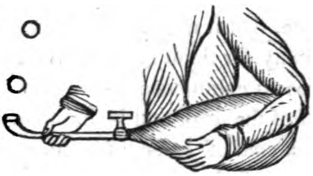
the iron and the hydrogen after it, the increase in the weight of iron and the weight of the hydrogen are just equal to that of the water. In this way the exact composition of water is determined analytically, and is found to be 8 parts of oxygen to 1 of hydrogen, and 1 vol. of the former to two of the latter.

* The zinc may be conveniently prepared by pouring a stream of the melted metal into cold water.

and when perfectly pure, inodorous. But as it is generally obtained, it has a fetid odor, arising from the oily matter which it contains, and the hydrosulphuric acid. It is a powerful refractor of light, and has never been condensed to a liquid.

It is the lightest body in nature. It is sixteen times lighter than oxygen, 36 times lighter than chlorine, 200,000 times lighter than mercury, and 300,000 times lighter than platinum!

Fig. 53.



Exp. Fill a gas bag with hydrogen* (fig. 53.); connect it with a bubble-pipe, and inflate soap bubbles with the gas; they will ascend rapidly, being forced up by the superior weight of the air. Or, if a jar of hydrogen be removed from the cistern, and inverted in the open air, the gas will immediately escape.

In consequence of its extreme lightness, hydrogen is used for filling balloons.

Fig. 55.

Aerostation. Roger Bacon first suggested the possibility of navigating the air by mechanical contrivances, but nothing of consequence was effected until 1782. The substance first employed to raise balloons was rarefied air, confined in a silk bag. Since the discovery of hydrogen, it has been universally employed for this purpose. Balloons are made of various shapes and capacities. The spherical form (fig. 55.) is the best, for the reason, that a given quantity of canvas, or silk made in the form of a sphere, will contain more than any other form, and hence offers the least resistance to the air. The substance employed for balloons is either varnished silk, or gold-beaters' skin, and

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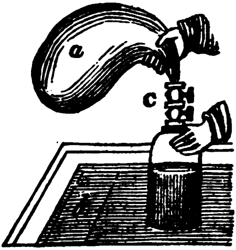
Fig. 54.



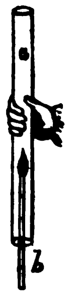
* The method of filling gas bags with gases from the pneumatic cistern, is represented in fig. 54. *b* is the cistern containing water; the receiver has a stop-cock in its top, upon which another stop-cock C, connected with the bag *a*, may be screwed. The receiver is filled with gas, and the stop-cocks being both open, is pressed down into the well, and the water presses the gas into the bag. Then by closing both stop-cocks, the bag may be removed from the receiver.

the size varies from 1 to 40 feet in diameter. They are generally covered with a net *n*, connected by cords to a small boat *c*, in which the aeronaut is stationed when he ascends. The hydrogen is prepared by putting iron turnings, sulphuric acid and water into several large casks, and connecting each with the balloon; the hydrogen is then rapidly evolved, and the balloon tied down until ready for use.

Chemical properties. Hydrogen has a strong affinity for many substances, and the energy of its combinations frequently produce the phenomena of combustion.

It is a *combustible* body, but not a *supporter of combustion.*

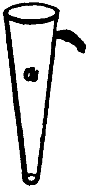
Fig. 56.



Exp. Plunge a lighted taper into an inverted jar of hydrogen, the gas will instantly be inflamed at the mouth of the jar, and burn with a blue light; but the taper, if wholly immersed in the gas, will be extinguished, and *relighted* again when the wick touches the flame.

Exp. Burn a jet of hydrogen. If the hydrogen be forced rapidly through a tube *b* (fig. 56.) with a small orifice, ignited at the orifice, and cylinders of glass as *a*, or other substances put over the flame, musical tones will be produced. The tones will vary with the size and kind of tube.

Fig. 57.



Exp. Mix two measures of hydrogen with one of oxygen, and apply the flame of a candle to a small portion confined in an exploding tube, or gas pistol *a* (fig. 57.), there will be a violent explosion. This effect is also produced by mixing one part of hydrogen with three of common air; but the explosions are much more violent when two vols. of hydrogen and one of oxygen are mixed and ignited with the flame of a candle; or, by the electric spark. Soap bubbles may be formed and exploded as they rise. A large bladder, filled with the mixture, may also be exploded by piercing it with a sharp wire on the end of a long rod, having about it ignited tow.

Exp. This mixture also explodes when suddenly compressed by the fire-syringe; this is owing to the development of its latent caloric, or because the particles are then brought within the sphere of each other's attraction—but the experiment is hazardous.

Theory. In these experiments, the report arises from the collapse of the air, a vacuum being formed by the sudden condensation of the gases. The musical tones arise from continued explosions produced by the union of the hydrogen and the oxygen of the air.

Exp. When a stream of hydrogen gas is brought in contact with spongy platinum, it is immediately set on fire.

This singular fact was discovered by Prof. Doebereiner of Jena in 1824. The sponge is prepared by dissolving platinum in nitro-muriatic acid, and then precipitating it with ammonia. Rhodium and iridium produce the same effect. This property has been applied to the construction of lamps, by which light can be easily and conveniently produced.

Under pressure, the combustion of hydrogen produces a very intense heat.

Exp. Burn a jet of hydrogen, and throw on iron filings, they will be ignited and produce beautiful scintillations. One pound of hydrogen in burning, will develope sufficient heat, according to Dalton, to melt 320 lbs. of ice.

Relations to animals. An animal soon dies when confined in it. This is not owing to the noxious properties of the hydrogen, since an atmosphere of oxygen and hydrogen will support respiration for a considerable time; but is due to the fact, that it excludes the oxygen, and thus suffocates. An atmosphere of oxygen and hydrogen has the singular property of producing a *most profound sleep.*

Hydrogen and Oxygen.

Protoxide of hydrogen, or water. 1 eq. H $1+1$ eq. O $8=9$ eq. Symb. $H+O$ or Aq. Sp. gr.$=1$.

Process. Water is the sole product of the combustion of hydrogen gas in common air, or oxygen. This may be shown by burning a jet of hydrogen in a large globe receiver; or, what will render the effect more striking, by burning a jet of two vols. of hydrogen, to one of oxygen with the compound blow-pipe: the sides of the receiver will soon become hazy, from the deposition of water upon its interior surface, and if the process be continued, large drops will form and run down the sides. This fact was first demonstrated by Mr. Cavendish, by burning the gases as above, and the weight of the water produced, was exactly equal to that of the gases consumed.

Physical properties. These are well known. It is transparent, colorless, inodorous and tasteless; slightly compressible by a very strong pressure; elastic; converted into vapor by heat; boils at 212° Far. and congeals at 32° Far. It is the standard of weight, with which all solid and liquid bodies are compared; its specific gravity is therefore 1. One cubic inch weighs 252.458 grs. It is 815 times heavier than the atmosphere, which is the standard of weight for gaseous bodies.

Chemical properties. 1. Water has the power of absorbing a great number of gaseous bodies. *It always contains air.*

Exp. This may be shown by placing it under the receiver of an air-pump, and exhausting the air, when bubbles of air will rise up through the water.

It is the air contained in water from which fishes obtain the oxygen necessary to purify their blood.

At the mean temperature and pressure, water will absorb, according to Henry and Dalton, of

Carbonic acid gas,	1 vol.	Carbonic oxide,	$\frac{1}{64}$ vol.
Sulphuretted hydrogen,	1 "	Carburetted hydrogen,	$\frac{1}{27}$ "
Nitrous acid,	1 "	Nitrogen,	$\frac{1}{64}$ "
Olefiant gas,	$\frac{1}{8}$ "	Hydrogen,	" "
Oxygen,	$\frac{1}{27}$ "		

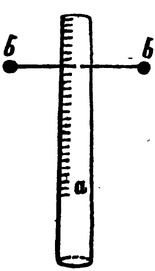
But if the gas be passed through the water under great pressure, a greater quantity will be absorbed. Carbonic acid gas, for example, is absorbed according to the pressure applied, to an unlimited extent.

2. *Water is one of the most powerful solvents in nature.* It enters into combination with various bodies; sometimes in indefinite proportions, as in solutions; at others in definite

proportions, as in the acids, some of the metallic oxides, and many salts in whose crystallization it is taken up, and in which it is therefore called the *water of crystallization.* The definite compounds are called *hydrates.** The affinity of water for some substances is so strong, that it cannot be entirely separated from them without at the same time decomposing the substance.

Composition of water. This has been accurately determined, both by analysis and synthesis. By synthesis, by burning 2 vols. of hydrogen and 1 of oxygen, the product is water. Also, by exploding 2 vols. of hydrogen and one of oxygen, in a strong glass tube, or *Eudiometer a* (fig. 58.), over mercury by the electric spark, there will be a perfect vacuum produced, and the mercury will rise, and fill the tube. Water may be decomposed by the galvanic battery, and the products are 2 vols. of hydrogen to 1 of oxygen. The same results are obtained by passing its vapor over red hot iron, and collecting the products.

Fig. 58.



Compound blow-pipe. This apparatus was invented by Dr. Hare in 1804. The best construction for experimental purposes is the following. AB (fig. 59.) are two cylinders of wood or copper open at the top, *c d* two similar cylinders open at the bottom, placed within the others, leaving spaces of ½ of an inch in width between them, and passing around cylinders of wood which nearly fill them. The spaces *ie* are filled with water, and the gases are conducted by a lead pipe into the bottom of *c* and *d*, which are the gasometers. As they are filled, they are lifted up by the weights. The tubes *h o* connect the gasometers with the blow-pipe; the gases being let out by means of stop-cocks. *d* is filled with oxygen and the gas passes in the tube *o* through the centre of the blow-pipe; *c* at the same time is filled with hydrogen and the gas passes in the tube *h* to the side of the blow-pipe, and issues at the point, so as to encircle the oxygen. By igniting the two gases, as they issue

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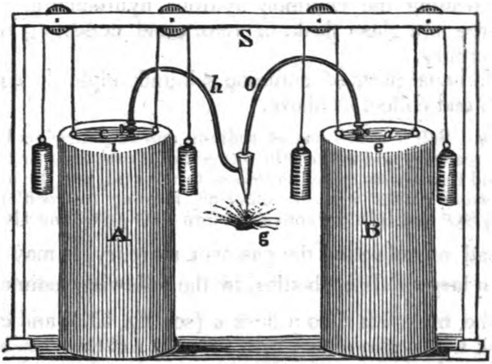
* The term *hydrous* is prefixed to substances containing water, and *anhydrous* to those deprived of it.

Fig. 59.



from the pipe, the heat is so intense as to melt the most refractory substances. It is only surpassed by that from a powerful galvanic battery. In burning the metals under the blowpipe, an opportunity is afforded for many interesting and beautiful experiments.

Binoxide of Hydrogen. Symb. $H+2O$ or HO^2, equiv. $1+16=17$. Sp. gr. 1.452, water = 1. This singular compound was discovered by Thenard in 1818, and is sometimes called *oxygenized water*, and *peroxide of hydrogen*. It is formed by the action of hydrochloric acid upon the peroxide of barium.

Properties. The binoxide of hydrogen is a colorless, transparent liquid, without odor, caustic to the skin, giving it a white stain, and possesses powerful bleaching properties. When heated to 59° Far., it is decomposed so rapidly as to *cause explosion;* the same effect is also produced by throwing it on to several of the oxides of metals; such as the peroxide of silver, lead, mercury, gold and some others.

Hydrogen and Chlorine—Hydrochloric Acid.

Symb. $H+Cl$. Eq. by vol. 200, by wgt. $35.42+1=36.42$. Sp. gr. 18.21 Hyd.=1, 1.2694 air =1.

History. This compound has been long known under the names of *spirit of salt*, and *muriatic acid;* but was discovered in its gaseous state, by Dr. Priestley, in 1772.

Natural History. It issues from the craters of volcanoes, and is found in the warm springs of Mexico; it exists in combination with ammonia, (the hydrochlorate of ammonia).

Process. 1. It can be obtained in the gaseous state, by simply heating the common hydrous hydrochloric acid of commerce in a glass flask, or retort, and collecting the gas over mercury.

2. Put equal parts of common salt and sulphuric acid into a retort, and collect as above.

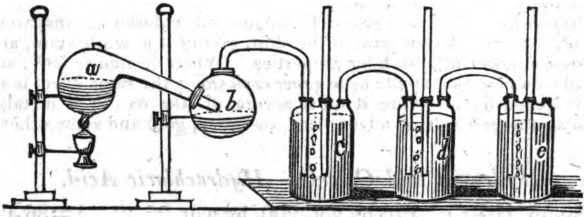
Theory. Salt is a chloride of sodium, and sulphuric acid is composed of real acid and water; the oxygen of the water goes to the sodium, and forms soda, which unites with the acid, and the hydrogen of the water unites with the chlorine, forming hydrochloric acid. $Na+Cl$, SO^3 and HO, are converted into $NaO+SO^3$ and HCl.

Instead of collecting the gas over mercury, it may be collected in large vials or bottles, in the following manner:

Put the materials into a flask *a* (see fig. 51.), and connect the flask with a glass tube, bent twice at right angles, and extending to the bottom of a bottle or receiver *b*; as the gas is heavier than the atmosphere, it will expel it and fill the bottle. By the application of ammonia to the mouth of the bottle, a white cloud will arise when the bottle is filled.[*]

Liquid hydrochloric acid. This is obtained in the arts, by passing the gas through water; for this purpose *Wolf's apparatus* may be employed.

Fig. 60.



It consists of several bottles, *b c d e* (fig. 60). The first bottle is connected by a lead tube, with a glass retort *a*, which contains the materials; *b* is one third filled with water; the tube from *b* descends to the bottom of *c*, and the gas passes up through the water. As soon as the water is saturated, the gas passes through the tube to the bottom of *d*, and ascends again through the water; thence to *e*, in a similar manner. Through the centre of each bottle there is a safety tube, extending nearly to the bottom, to prevent the danger that might arise from a too sudden evolution of gas. The gas presses upon the surface of the water, and forces it up the centre tubes, which prevents it from bursting the bottles. The acid in the first bottle is thrown away, the rest is the acid of commerce. The bottles should be surrounded with ice, to aid the absorption; water will thus absorb 480 times its volume, and the solution has a density of 1.2109.

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[*] All gases, that are heavier than the atmosphere, may be collected in this way, and those that are lighter may be collected by inverting the bottle and pressing the air down instead of lifting it up.

Physical Properties Hydrochloric acid gas is colorless, of a pungent odor, and acid taste, a little heavier than the air; sp. gr. 1.269; under a pressure of forty atmospheres, or 600 lbs. on the square inch, it is condensed into a liquid.

Chemical properties. It possesses decidedly acid properties, changes the vegetable infusions red, and combines with alkalies, and forms salts. It supports combustion feebly, and extinguishes a lighted taper, the flame of which assumes a greenish hue before it goes out. Water absorbs it rapidly.

Exp. A drop or two of cold water, introduced into a flask of the acid, will absorb it readily; and if a jar of it be inverted over water, the water will rush in with nearly the same violence as into a vacuum.

Exp. So strong is its affinity for water, that a piece of ice introduced into a jar of it over mercury, will be dissolved almost as soon as if thrown into a furnace.

It is readily decomposed by voltaic electricity, the hydrogen appearing at the negative and the chlorine at the positive pole. A discharge of ordinary electricity will decompose it, but, according to Henry, the second shock causes it to combine again. It is decomposed by those substances which yield oxygen readily, such as the peroxide of manganese, cobalt, and lead; the oxygen combines with the hydrogen of the acid, and sets the chlorine at liberty.

It is nearly as *suffocating* when taken into the lungs as chlorine, causes spasms of the glottis, and combines with the saliva, or water, and forms the liquid acid.

Constitution. It was formerly supposed to be a simple body, combining with oxygen to form oxymuriatic acid, now found to be chlorine. But its composition may be determined synthetically, by mixing equal portions of hydrogen and chlorine in a glass tube, and exposing them to the solar rays, when they instantly combine with explosion, and hydrochloric acid is the only product; or their union may be effected by passing an electric spark through the mixture contained in the eudiometer.* If the gases are mixed they will combine slowly in diffuse day-light. The light from the points of charcoal, at the poles of a galvanic battery, has the same effect as the sun's rays.

Uses. Hydrochloric acid is one of the three great acids used in the arts; for preparing the chloride of tin for dyers; as a re-agent in various chemical processes, and in medicine as a tonic.

Impurities. The acid of commerce is not quite pure, containing the chloride of iron, and chlorine. This gives the liquid a yellow color, but when perfectly pure, it is limpid.

Hydriodic acid. Symb. $H+I$. Eq. $126.3+1=127.3$. Sp. gr. 4.3854, air $=$ 1. Discovered by Gay Lussac of Paris.

Preparation.—It may be obtained by passing iodine vapor and hydrogen gas through a red hot porcelain tube. But a more convenient process by which it may be obtained, for the purposes of experiment, is to put a small bit of phosphorus into a glass tube, filled with water, and drop upon it a few grains of iodine. The iodine unites with the phosphorus, forming the periodide of phosphorus, and then the water and the periodide mutually decompose each other. The oxygen of the water unites with the phosphorus, and the hydrogen with the iodine, giving rise to phosphoric and hydriodic acids; the latter passes over in the form of a colorless gas, and may be collected in a receiver of common air; it may be passed through water and absorbed by it. It cannot be collected over mercury, because it acts upon it.

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* The fact being established that hydrochloric acid is composed of hydrogen and chlorine, the old theory that oxygen was the only acidifying principle is proved false; there are many acids of hydrogen which have no oxygen in them.

Properties. Hydriodic acid is a colorless, transparent gas, very sour to the taste, and gives an odor like hydrochloric acid; reddens vegetable blues without destroying them, and, when mixed with air, produces dense white fumes; has a strong affinity for water; is decomposed by several of the metals, such as potassium, sodium, zinc, iron, and mercury, and even when exposed to the air.

Uses. This acid may be employed to form pigments.

Exp. Take some of the salts of lead, in solution, and pour on hyriodic acid; it will decompose the salt, and form paints of a yellow color.

Tests. The most delicate test of this acid is *bichloride* of platinum, a single drop of which, in solution, will give to a liquid containing the acid, a reddish brown color, and a dark precipitate will subside.

Exp. Starch is also a sure test. A few drops of sulphuric acid will give to a solution of the acid, mixed with a cold solution of starch, a blue color.

Hydrobromic acid. Symb. $Br+H$ or BrH. Eq. $78.4+1=79.4$. Sp. gr. 2.7353. Discovered by M. Balard, and may be obtained by immersing a red hot iron into a mixture of the vapor of bromine and hydrogen; the combination takes place slowly without explosion, or it may be formed for experimental purposes, by a process similar to that for obtaining hydriodic acid, using bromine instead of iodine.

Properties. It is colorless, with an acid taste, and pungent odor; irritates the glottis, so as to excite coughing; exposed to moist air, it yields white dense vapors, and is rapidly absorbed by water; decomposed by chlorine instantly; nitric acid also effects its decomposition.

Hydrofluoric acid. Symb. $F+H$ or FH. Eq. $18.68+1=19.68$. Sp. gr. 1.0609.

History. First procured in a pure state in 1810, by Gay Lussac and Thenard.

Process. It is formed by the action of sulphuric acid on fluor-spar (*fluoride of calcium*). This mineral is pulverized, put into a lead or silver retort, with twice its weight of sulphuric acid, and heat applied. The acid will distil over, and must be collected in a vessel of the same material, surrounded with ice to condense the acid.

Theory. The hydrogen of the water in the sulphuric acid, combines with the fluorine in the mineral, and the oxygen with the calcium. The sulphuric acid, unites with the oxide of calcium, the products are *hydrofluoric acid,* and *sulphate of the protoxide of calcium.* Ca, F, SO^3 and HO are converted into $CaO+SO^3$ and FH.

Properties. At 32° Far. it is a colorless liquid, and remains in that state at 59°, if preserved in well-stopped bottles; but, exposed to the air, it assumes the gaseous form, unites with the water of the atmosphere, producing white fumes. Its affinity for water is greater than strong sulphuric acid. Its vapor is much more pungent than chlorine or any of the irritating gases; *the most destructive to animal matter* of any known substance—a single drop of the concentrated acid causing deep and almost incurable ulcers. It is distinguished for the remarkable property of acting on glass. It readily dissolves silex, and an acid is produced called the *fluo-silicic acid,* and hence it cannot be preserved in glass vessels.

Uses. It is used for etching on glass.

For this purpose, prepare some resin or beeswax, and form a coat over the glass; then, with a pointed instrument, remove the coating where you wish the glass to be etched; pour on the acid, and in a few minutes the etching is completed; by washing the glass in water, and removing the coating, the figures will appear.

SECT. 7. NITROGEN.

Symb. N. Equiv. $\left\{\begin{array}{l}\text{By vol. } 100.\\ \text{“ wgt. } 14.15.\end{array}\right.$ Sp. gr. $\left\{\begin{array}{ll}0.9727 & \text{Air } =1.\\ 14.15 & \text{Hyd.}=1.\end{array}\right.$

History. Nitrogen was discovered by Dr. Rutherford of Edinburgh in 1772. Three years after, Lavoisier discovered that it was a constituent of the atmosphere. Scheele also made the same discovery. It was called by Lavoisier *azote* (from two Greek words*), because it deprived animals of life; but this is not the only gas which is *azotic.* Its present name, *nitrogen,* is derived from nitre (nitrate of potassa).

Natural History. Nitrogen exists in all animals, in fungous plants, and constitutes $\frac{4}{5}$ of the atmosphere; also in some hot springs in Scotland, and in the Alps. It is also evolved from certain springs in New York.

Process. It may be obtained from the atmosphere, either by burning out the oxygen of a confined portion of air with some combustible, or by abstracting the oxygen in a more gradual way, by its affinity for some of the simple substances.

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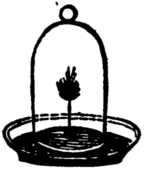
* α and ζωή.

Fig. 61.



Exp. 1. Put a small piece of phosphorus in a cup which will float on water (fig. 61.), and invert over it a receiver of common air. On igniting the phosphorus, it will unite with the oxygen, and burn until all the oxygen is consumed, forming white fumes—the pyrophosphoric acid. This acid, in a short time, will be absorbed by the water, which will rise and fill the jar $\frac{1}{5}$ full. This is sufficiently pure for common experiments, but contains vapor of phosphorus and carbonic acid, which may be removed by passing the gas through pure potassa.

Exp. 2. Make a paste of flour of sulphur and iron filings, and invert over it a receiver; the oxygen will combine slowly with the iron, and leave the nitrogen. A stick of phosphorus will produce the same effect. If the proto-sulphate of iron, charged with the binoxide of nitrogen be substituted for the paste, the process is more rapid.

Exp. 3. It may also be obtained, by pouring nitric acid on fresh muscle, and subjecting it to a moderate heat.

Theory. On account of the strong affinity of oxygen for these substances, it leaves the nitrogen and combines with them.

Physical properties. Nitrogen is colorless, tasteless, inodorous, not condensed into a solid by pressure, or cold; 100 cubic inches weigh 30.1650 grains.

Chemical properties. Water, recently boiled, absorbs $1\frac{1}{2}$ vols. of the gas. *It will not support combustion.*

Exp. Put a lighted candle into a jar of it, and it will be immediately extinguished; hence *it does not support respiration.*

No animal can live in it, not because of the active properties of the gas, but because it excludes the oxygen. It kills by its negative properties, for which it seems alone to be distinguished. The effect is like that of drowning.

Although pure nitrogen is the most inert of substances, some of its compounds are among the most active and useful.

Nitrogen and Oxygen.

Common air. Symb. $2N+O$. Equiv. $28.30+8=36.30$, eq. vol. $4N+O$. Sp. gr. $=1$. The earth is surrounded by a gaseous fluid or atmosphere, consisting chiefly of common air, extending about forty-five miles from its surface, and revolving with it around the sun.

Physical properties. The atmosphere is a permanent, elastic fluid, transparent, inodorous and tasteless. The air is very compressible and elastic.

The *compressibility* of the air may be shown by the fire-syringe, by which it may be compressed into a very small compass. If 100 measures of confined air under pressure of 1 lb. be subjected to double the pressure, or 2 lbs., it will be diminished to 50 measures; double this pressure, or 4 lbs., will compress it to 25 measures. On the other hand, if the pressure be diminished, its elasticity will restore it to its former state. Then if $\frac{1}{2}$ lb. be applied to the 100 measures, it will expand to 200 measures. Halve this, or $\frac{1}{4}$ of a pound, and the vol. will be double, or 400 measures. The same is true of all other gaseous bodies, while they retain their gaseous state. Hence the following law, that *the volume of air and of other gaseous fluids is inversely as the pressure applied.*

The *elasticity* of the air may be further shown, by putting a bladder, half filled with air, under the receiver of an air-pump, and exhausting the air from the receiver; the external pressure being thus taken off, the air within the bladder will expand, fill the bladder, and even burst it. This force is often so great, as to burst the strongest vessels. Hence the danger of forcing too much air into the ball of an air-gun, or carbonic acid into a soda fountain.

Winds. In consequence of the great elasticity and compressibility of the air, it gives rise to the phenomena of winds. It is subject to the laws of elastic fluids in general; as one portion therefore becomes expanded by heat, the colder or more dense portions rush rapidly into its place, and force it to ascend. From the same properties also, vibrations are easily produced in it, which give rise to the sensation of sound, musical tones, etc.

Pressure of the air. That the air had weight, was first noticed by Galileo in 1640. Torricelli, his pupil, carried out his suggestions, and in 1643 invented the *barometer*, by which variations of pressure could be accurately measured. The exact weight of the atmosphere is of great importance in physical and chemical researches, and has been accurately determined by Dr. Prout. At the level of the sea, its pressure is 15 lbs. on every square inch of surface. (See page 36.)

Exp. This pressure may be illustrated by exhausting the air from the receiver of an air-pump; the pressure on the external surface of the receiver will fix it immoveably to the plate.

The body of a man sustains constantly a pressure of about 14 tons!

As we ascend above the level of the sea, the mercury sinks in the barometer, because the column of air is shorter; hence the height of mountains may be measured in a very expeditious manner. Æronauts, in this manner determine the height to which they ascend.*

Extent of the atmosphere. The height of the atmosphere, as estimated by the phenomena of refraction, is found to be about forty-five miles. Above that height no refraction takes place in the rays of light. Dr. Wollaston estimates its extent by the law of the expansion of gases, at forty miles. That is, the *weight* of the particles of air (gravity) will overcome their elasticity at that height.

Composition of the atmosphere. Chemists are not agreed whether the atmosphere is a chemical or a mechanical compound. The proportions 20 or 21 parts of oxygen and 79 or 80 of nitrogen in 100 never vary, from whatever parts of the earth, or regions of the atmosphere, it may be taken. Gay Lussac brought air from an altitude of 21,735 feet, and its composition did not vary from that on the surface of the earth.†

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* There seems to be a constant relation between the pressure of the atmosphere and the weather. During a storm, the mercury in the barometer sinks, indicating that the atmosphere is lighter, and rises again when fair weather returns, proving its greater weight. Invalids often complain of the oppressive weight of air in foul weather; the fact as we have seen, is the reverse; they feel a difficulty in respiration, because the air is too light. The same difficulty is felt by æronauts, and those who ascend high mountains.

† This uniformity in its composition has been regarded as a decisive proof of its chemical constitution; on the other hand there is

Impurities. The air usually contains other gases; carbonic acid, and watery vapor, are the most abundant. The quantity of water is determined by the hygrometer. It never amounts to more than one per cent. Carbonic acid rarely exceeds $\frac{1}{1000}$. Traces of hydrochloric acid are frequently found in the vicinity of the ocean, and of nitric acid in rain water, produced by lightning.

The air near cities often contains other substances, organic matter, sulphuric acid, and ammonia. The odoriferous particles of flowers, and other vegetable and mineral substances, are often detected in it.

It was formerly supposed, that the healthy state of the air depended upon the proportion of oxygen in it; hence the origin of the term *Eudiometry*, which was applied to the process of analyzing the air; but since the oxygen of the air is found to be constant, it is now applied also to the modes of ascertaining its purity. This is effected, either by exploding a given portion of air with hydrogen in the *eudiometer*, (see page 142), or by placing in a portion of confined air, some substance to abstract the oxygen.

Uses of the air. The utility of the atmosphere in the economy of nature cannot be to highly rated. It is absolutely essential to animal and vegetable life, and is one of the most beautiful illustrations of the wisdom, and goodness of the Creator.

Protoxide of nitrogen. Symb. NO. Equiv. 14.15+8=22.15. Sp. gr. 1.5239; 100 cub. in. weigh 47.2586 grs.

History. Discovered by Priestly 1772, and named by him *dephlogisticated nitrous air.* Davy called it *nitrous oxide.*

Process. This gas may be formed by decomposing nitrate of ammonia.

Exp. Put a few grains of this salt into a glass retort, and apply heat. At a temperature of between 400° and 500° Far. it liquifies, bubbles of gas begin to appear, and in a short time brisk effervescence. The gas may then be collected in the ordinary way over warm water, and suffered to remain a short time, until the water absorbs the nitrous acid, which is often formed with it.

Theory. The changes which take place may be thus ex-

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good reason for considering it a mechanical mixture. It seems to be a peculiar case, different from other mixtures, for the benefit of the *animal* and *vegetable kingdoms.*

plained: the NH^3+NO^5, containing 2N, 5O and 3H, are converted into 3HO, or water and 2NO.

Properties. The protoxide of nitrogen is a colorless, inodorous gas, of a sweetish taste, and does not affect the vegetable blues; it is not, therefore an acid, or an alkali.

It supports combustion.

Exp. A candle is relighted in the same manner as in oxygen gas. Iron ware, charcoal and most combustibles burn in it. Phosphorus burns with nearly the same brilliancy as in oxygen, but generally it requires the temperature of the substance to be raised to a higher degree than oxygen, because the heat is necessary to decompose the salt, so that its oxygen may unite with the combustible, and its hydrogen escape into the air.

Respiration of this gas. When respired, it is a *powerful stimulant.* Its effects upon the animal system were first investigated by Sir H. Davy in 1799. In his experiments on the effects of respiring the various gases, he breathed nine quarts of this gas for three minutes, and twelve quarts for four. *No quantity would support respiration for a longer period.* The effects are pleasurable in the highest degree, resembling the first stages of intoxication. The effect varies very much with temperament, but *generally* gives an unusual propensity to *muscular action*, a rapid flow of vivid ideas, and the *more prominent* traits of character made *still more prominent.*

This excitement continues but for a few minutes, and generally is not succeeded by the languor and exhaustion, consequent upon other stimulants.* Its effects, however, upon some temperaments have proved decidedly injurious. It is hoped that so powerful a stimulant will be applied to some good use in medicine.

Binoxide of Nitrogen. Symb. $N+2O, NO^2$, or $\ddot{N}$. Equiv. $14.15+16=30.15$. Sp. gr. 1.0375.

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* It may be administered from a silk or india-rubber bag, furnished with a stop-cock, by repeatedly breathing it from the bag and back again as long as it will support easy respiration.

History. Discovered by Dr. Hales, but its properties were first investigated by Dr. Priestly in 1772, who gave it the name of *nitrous air*, *nitric oxide*, and *nitrous gas* have also been applied to it.

Process. It may be formed by the action of dilute nitric acid; (2 parts of water to 1 of acid) upon copper filings, or mercury. Place the materials in a retort and collect over water.

Theory. In this process the nitric acid is decomposed. 3 equiv. of oxygen unite with the copper, forming the peroxide of copper, and 2 equiv. of oxygen combine with the nitrogen and form the binoxide; the peroxide of copper is then united to some undecomposed nitric acid, and forms the nitrate of copper. Cu and $2NO^5$ are converted into CuO^3+NO^5 and NO^2

Properties. This gas is colorless, and slightly absorbed by water. It is perfectly *irrespirable*, exciting spasms in the glottis, which immediately closes to prevent its passage into the lungs. It extinguishes most burning bodies, although phosphorus and charcoal, introduced in a state of vivid combustion, burn with increased brilliancy, owing doubtless to its decomposition, which is easily effected by heat or electricity.

It has a strong affinity for oxygen.

Exp. Pass oxygen into a jar of it, and red fumes will be formed. This is a test of the gas. Atmospheric air will produce a similar effect.*

Hyponitrous acid. Symb. $N+3O$, NO^3 or $\dddot{N}$. Equiv. $14.15+24=38.15$. This compound was discovered by Gay Lussac, and is said to be formed when 400 measures of binoxide of nitrogen are mixed with 100 of oxygen, both quite dry. When the resulting orange fumes are exposed to a cold of zero, Far. they are condensed into a liquid. The *anhydrous* acid is colorless at zero, Far. and green at common temperatures. It is so volatile, that in open vessels, the green fluid wholly and rapidly passes off in the form of an orange-colored vapor, density of 1.72. In the manufacture of sulphuric acid, it exerts an important agency, by forming with water and sulphuric acid a crystalline compound, the production of which, seems essential to the process.

Nitrous acid. Symb. $N+4O$ NO^4 or $\ddddot{N}$. Eq. $14.15+32=46.15$.

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* Owing to this property, an attempt has been made to introduce it into *eudiometry*, but the results are not perfectly satisfactory.

History. Known for some time under the name of *fuming nitrous acid.* Its true nature has been ascertained by Davy, Gay Lussac and Dulong.

Process. It is formed by adding oxygen gas in excess to the binoxide of nitrogen over mercury, and putting a strong solution of potassa into the receiver before mixing the gases; red fumes appear, and combine with the potassa, forming the nitrate of potassa.

It may be obtained in the form of a gas, by exhausting a glass globe of air, and introducing 100 vols. of oxygen to 200 vols. of the binoxide of nitrogen.*

The best mode is to expose, in an earthen retort, nitrate of lead carefully dried, to a red heat—and collect the gas in a tube surrounded by ice. For the purposes of experiment, it may be formed by introducing oxygen, or common air into a jar of the binoxide, over water; deep orange red colored fumes appear, which are rapidly absorbed by the water; or by simply taking up a jar of the binoxide, and exposing it to the air. In each case, nitrous acid is formed, and may be known by its red fumes.

Properties. The vapor is of an orange red color, rapidly absorbed by water. At common temperatures, the liquid is orange red; below 32° yellow, and nearly colorless at zero, Far. Density 1.451; anhydrous, exceedingly volatile, pungent to the taste, and powerfully corrosive, giving a yellow stain to the skin.

It has decided acid properties,† both in the gaseous and liquid states.

Exp. Into a long glass tube, filled partly with vegetable infusion, and partly with the binoxide, introduce a few bubbles of oxygen, and the fusion will immediately turn red, owing to the formation of NO^4.

Respiration of nitrous acid. It is highly suffocating and poisonous, exciting great irritation and spasms in the glottis, even when moderately diluted with air.

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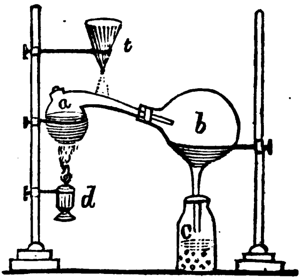
* If collected over water, it is converted into nitric acid; if over mercury, it is decomposed and the mercury is oxidized.

† Some chemists believe it to be a compound of nitric and hyponitrous acids, from the fact that when it is added to an alkaline solution, the products are a *nitrate* and a *hyponitrite* of the base.

Nitric acid. Symb. $N+5O$, NO^5 or $\overset{\therefore\cdot}{N}$. Equiv. $14.15+40=54.15$.

History. This acid was first discovered in distilling a mixture of *nitrate of potassa and clay*, by Raymond Lully, a chemist of the island of Majorca. Basil Valentine, in the 15th century, describes a process of obtaining it, and calls it the *water of nitre.* Its composition, however, was first determined by Mr. Cavendish in 1785, by exposing oxygen and nitrogen in a glass tube over mercury, in which some water was present, to the action of the electric battery. It has since been examined by Davy, Dalton, Henry, Berzelius, and Gay Lussac.

Fig. 62.



Process. Gay Lussac obtained nitric acid by adding the binoxide of nitrogen slowly to an excess of oxygen over water. By this process, it is found to be composed of 250 vols. of oxygen to 100 of nitrogen. But the usual process for obtaining it, is to heat in a large tubulated retort *d* (fig. 62.) a mixture of 3 parts of nitre (nitrate of potassa) and 2 of sulphuric acid,* and condensing the gas in the globe-receiver *b*, by dropping ice-cold water from the tunnel *a* upon the tube of the retort, or by surrounding the receiver *b* with ice. The liquid as it is condensed passes into the bottle C.

Impurities. The acid of commerce is not perfectly pure; three acids are generated in the process, the nitrous, hyponitrous and nitric. It also contains hydrochloric and sulphuric acids. Nitrous acid gives it a color varying from yellow to orange and green, and may be expelled by heat; the hydrochloric may be detected and separated by a few drops of the nitrate of silver, with which it will combine and form a white solid. The sulphuric acid is separated by re-distilling it with nitre.

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* The London college of physicians employ equal weights of nitrate of potassa and sulphuric acid. The Edinburgh and Dublin colleges employ 3 of nitre to 2 of acid. According to Thompson, the strongest acid is obtained from 6⅛ parts of sulphuric acid to 12¾ of nitre. The specific gravity of which is 1.55

Properties. Nitric acid, in its most concentrated state, is a white or limpid liquid, specific gravity of 1.55, and of a peculiarly nauseous odor. It boils at 248°, and freezes at –50° Far.

Chemical Properties. It is one of the most energetic of substances. It acts upon the skin, and gives it a yellow stain; it is eminently poisonous; has a very strong affinity for water, and cannot be wholly separated from it, before decomposition takes place.

It acts as a supporter of combustion; in this case, it is decomposed, and the oxygen combines with the combustible.

Fig. 63.

Exp. Pass hydrogen and nitric acid through an ignited porcelain tube, a violent detonation will be produced.

Exp. Pour strong nitric acid on dry powdered charcoal—the charcoal will be ignited, with the evolution of dense fumes.

Exp. Phosphorus takes fire in it (fig. 63.), sometimes with violent explosion.

Exp. Pour nitric acid on to some of the essential oils, spirits of turpentine, and they will be inflamed.

The acid in these experiments should be poured from a wine-glass, attached to the end of a long rod.

It unites with various metals, such as iron, tin, copper, with great energy, and is decomposed by them. It also suffers decomposition by boiling it in contact with sulphur, or by exposing it to the solar rays. In this case, the color changes to a yellow, and deep orange, in consequence of the formation of *nitrous acid.* The action of the binoxide of nitrogen produces the same effect, as may be shown by passing it through nitric acid. In consequence of its yielding up its oxygen so readily, it is one of the most powerful oxidizing agents.

Uses. It is used extensively in chemistry, and the arts: for etching on copper, and as a solvent of tin to form a mordant for some of the finest dyes; in metallurgy and assaying, to bring the metals to their maximum of oxidation; in medicine, as a tonic. The nitric acid of commerce is ½ water, and called *double aqua fortis*—another kind, ¾ water, called simply *aqua fortis.*

Nitro-muriatic acid. This is the *aqua regia* of the alchemists, and is formed of 1 part of nitric, to 4 of hydrochloric acid.

It possesses the remarkable property of dissolving gold and platinum, but does not form a distinct class of salts.

Nitro-hydrofluoric acid. This acid is formed by a mixture of nitric and hydrofluoric acids, and dissolves metals, which are not dissolved by the preceding acid, and is therefore an important re-agent.

Nitrogen and Chlorine.

Quadro-chloride of nitrogen. Symb. $N+4Cl$ or NCl^4. Eq. $14.15+141.68=155.83$. Sp. gr. 1.653. Discovered in 1811 by Dulong, and subsequently examined by Davy, and others.

Process. This very extraordinary substance may be formed by the union of nitrogen and chlorine in their nascent state, or the chlorine may be obtained in a jar and inverted over a solution of 1 part of hydrochlorate of ammonia, to 12 of water; a part of the chlorine unites with the hydrogen of the ammonia, forming hydrochloric acid, and another portion unites with the nitrogen of the ammonia, and forms the quadro-chloride of nitrogen, which appears in the form of yellow, oily drops on the surface of the solution.

Properties. A yellow oily liquid, of an irritating and peculiar odor; it retains the liquid state below zero, Far. It may be distilled at 160° Far., but explodes between 200° and 212°, and suffers decomposition. It is one of the most explosive substances yet known. A drop of the size of a pea, brought in contact with phosphorus, or with any of the oils, will explode with great violence. It is dangerous to experiment with it, even in so small portions. Dulong lost an eye and a finger, and Davy had both eyes injured by exploding small quantities of it. It is liable to explode without any assignable cause.

Nitrogen and Iodine.

Teriodide of Nitrogen. Symb. $N+3I$ or NI^3. Eq. $14.15+378.9=392.24$. This compound, discovered by M. Courtois, is obtained in a similar manner with the preceding.

Exp. Put iodine in a solution of ammonia, and there will be precipita-

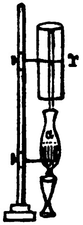
ted a blackish powder, which may be thrown, in the course of half an hour, upon a filter, washed and dried. When dry, it explodes by the slightest touch, or even spontaneously.

Nitrogen and Hydrogen.

Ammonia. Symb. $N+3H$ or NH^3. Eq. $14.15+3=17.15$.

History. This substance was known to the alchemists by the names of *hartshorn*, *volatile alkali*, *spirit of sal-ammoniac*, etc., but was first noticed as a distinct gas by Dr. Priestly, who gave it the name of *alkaline air*. The name *ammonia* is derived from one of the salts from which it was procured, the hydrochlorate of ammonia, or sal-Ammoniac, and this from the temple of Jupiter Ammon in Lybia, from which place it was first obtained.

Fig. 64.



Process. Mix together equal parts of pulverized hydrochlorate of ammonia and recently slacked lime in a common retort, and apply heat. The gas may be collected over mercury, or in consequence of its being lighter than the air, the materials may be put into a Florence flask *a* (fig. 64.), to which is attached a long glass tube. Invert over it a receiver *r*, and the gas will displace the air and fill the receiver—(for a test of the gas, hydrochloric acid may be used, which produces a white cloud). It may also be obtained by simply heating the common aqua ammonia of commerce. The *liquid ammonia* is preparéd by passing the gas through water in Woulf's apparatus, in the same manner as in the preparation of hydrochloric acid. (See page 144.)

Properties. Ammonia is a colorless gas, of a strong, pungent odor; becomes a transparent liquid under pressure of 6.5 atmospheres, and at a temperature of 50° Far. It cannot support respiration in its pure state, but may be inhaled with safety, when mixed with the air.

It is inflammable, but extinguishes the flame of most burning bodies.

Exp. A candle immersed in this gas, burns with increased flame, tinged with yellow before it goes out. When expelled from an orifice surrounded by oxygen gas, and ignited, it burns with a pale yellow flame. The products are water and nitrogen.

It has a strong affinity for water.

Exp. A few drops of water introduced into a jar of the gas over mercury, will instantly absorb it, and the mercury will rise.

Ice is melted in it. Alcohol absorbs several volumes of this gas, and the solution has a strong odor, commonly called *spirits of hartshorn.*

Decomposition is effected by chlorine and iodine.

Exp. Place a flask of ammonia over a bottle with a wide mouth, containing chlorine gas. The gases will instantly combine, as will be seen by a sheet of white flame.

Theory. The chlorine unites with the hydrogen of the ammonia, forming hydrochloric acid, and this unites with some undecomposed ammonia, and forms hydrochlorate of ammonia, and will be deposited on the sides of the flask in a solid state.

*It possesses decided alkaline properties.**

Exp. Place a jar of ammoniacal gas on to a plate containing vegetable infusion, and the infusion will become green.

Uses. Ammonia is used in the arts, and in medicine. In chemistry it is employed to neutralize acids.

Exp. Colors changed by acids, may often be restored by ammonia.

In medicine, it is used as a tonic. It is a powerful and grateful stimulant, producing the useful effects of alcohol, without its injurious consequences. Ammonia is the substance employed for smelling bottles.*

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* This introduces to us a new class of bodies—the alkalies. Ammonia is the only one the base of which is not a metal, and there is still some doubt whether its base, nitrogen, is not a body with a metallic base. This view corresponds best with the general analogy of other compounds. The alkalies generally have the following properties.

1. Caustic to the animal organs, corrode woollen cloth, and are generally powerful solvents of animal matter.
2. Volatilized by heat, but excepting ammonia, are not easily decomposed by it.
3. Combine with acids, and form salts.
4. All soluble in water.
5. Unite with oils, and form soaps.
6. Taste acrid, very different from acids.
7. Change some vegetable blues to green. This last property is a convenient one to distinguish them from acids. One of the best tests of acids and of alkalies, is an infusion of purple cabbage, which is changed to red by acids, and to green by alkalies.

SECT. 7. CARBON.

Symb. C. Equiv. $\left\{\begin{array}{l}\text{By vol. 100.}\\ \text{“ wgt. 6.12.}\end{array}\right.$ Sp. Gr. $\left\{\begin{array}{l}\text{3.52, Water} = 1.\\ \text{6.12, Hyd.} = 1.\end{array}\right.$

Natural History. Carbon is one of the most important and useful of substances. Like all other substances of extensive utility, it is widely diffused. It exists abundantly in the animal, vegetable, and mineral kingdoms. The greater part of the substance of trees, and of animal bodies, is carbon. It is rarely found quite pure in nature, and cannot be formed perfectly pure by art. The only pure carbon is the diamond.

The diamond is found in the East Indies and in Brazil, S. A. They generally occur in alluvial soils, in detached crystals, the primitive form of which is the regular octahedron, but sometimes have twenty-four, and even forty-eight faces. They are of various colors, brown, black, red, blue and green, or colorless and transparent; the latter are the most valued.† The diamond is the hardest body in nature. It is a powerful refractor of light, a property which led Newton to predict its combustion. Lavoisier first proved it to contain carbon, by exposing it in oxygen gas to the solar focus. The product was carbonic acid. In 1807, the combustion of the diamond in oxygen, was found by Allen and Pepys to be attended by the same results as that of charcoal. Davy confirmed these results by comparing the combustion of the diamond with that of various kinds of charcoal. Another proof of its identity is the fact, that diamond converts iron into steel in the same manner as charcoal.

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[*] To prepare a smelling-bottle, it is only necessary to put a small quantity of quick lime and hydrochlorate of ammonia into a small bottle, and keep it corked tight, only when it is used.

[†] Diamonds are of various sizes; some are as large as a pigeon's egg, and the value increases with the size, in a very rapid ratio.

Uses. The diamond is the most valued of gems: used in jewelry, and for the purpose of cutting glass.

The other kinds of carbon are the following:

Plumbago. This is carbon nearly pure, containing four or five per cent. of iron. It is sometimes called *black lead*, and used for pencils, crayons, etc. It is found native in primitive formations, and is next to the diamond in purity.

Anthracite is a species of fosil coal, the next in purity.

Bituminous coal is similar to the preceding, with the addition of bitumen, when the bituminous, and volatile matter is driven off by heat; it is called *coke*, which is nearly pure carbon.

Peat is an impure kind of carbon, containing uncarbonized vegetable matter, mixed with earthy substances.

Lampblack is a kind of carbon which is obtained by the combustion of turpentine, pitch-pine, camphor, and almost any species of combustible matter, containing carbon. It is deposited from flame in the form of a fine black powder. For use in the arts, it is chiefly made by turpentine manufacturers, from the refuse resin. This is burned in a furnace, and the smoke, carrying up the carbon, is conducted to a room hung with sacking, upon which the lampblack is deposited. It is collected and sold without further preparation. It is used extensively as a paint—that from camphor is the best.

Ivory black is a kind of lampblack obtained from burning bones, sometimes called *animal charcoal.*

Charcoal. If wood be burned in the open air, nothing remains but ashes; but if the air is mostly excluded, so that it undergoes a smothered combustion, a black brittle substance remains called *charcoal*, which is nearly pure carbon.

Processes. 1. For the common purposes of fuel, it is prepared by forming the wood into a conical pile and covering it with earth. The combustion is slow, in consequence of the small quantity of air which is admitted; the volatile parts are driven off, and the carbon remains.

2. It is also prepared by distillation of wood, in large iron

cylinders. This is the mode of preparing it for the manufacture of gunpowder. Beside the charcoal, two valuable substances, the pyroligneous acid, and tar are obtained.

3. But the purest charcoal is prepared by charring wood under sand, or melted lead. It should be put immediately into bottles, corked tight, to exclude the air.

Properties. Carbon is a black, brittle, shining, inodorous substance, easily pulverized, a good conductor of electricity, and a bad conductor of caloric.

It is the hardest substance in nature. Common charcoal appears soft, but this is in consequence of its pores. If rubbed upon glass it will scratch it.

It has the property of absorbing various gases.

Exp. Heat a piece of charcoal and plunge it into mercury until cool, then place it under a glass receiver over mercury. In the course of twenty-four or thirty-six hours, it will absorb of ammonia, 90 times the volume of the charcoal:

Hydrochloric acid,	85	Olefaint gas,	35
Sulphurous acid,	85	Carbonic oxide,	9.42
Hydrosulphuric acid,	55	Oxygen,	9.25
Protoxide of nitrogen,	40	Nitrogen,	7.5
Carbonic acid,	35	Hydrogen,	1.75

The gases will be given up again by heating the charcoal, or partially by ***plunging it into water.***

Theory. This power cannot be attributed wholly to chemical action, but is due to the porous texture of the charcoal, and the gases appear to be absorbed in the same manner that sponges and other porous bodies absorb liquids. The property is most remarkable in the compact varieties, such as that from box-wood, where the pores are numerous and small. By reducing it to powder, this power is diminished. In plumbago, and in the diamond it is wholly wanting.

But how does this account for its absorbing more of one gas than of another? Chemical affinity has doubtless some influence, but it is mostly due to the *elasticity* of the gases. Those gases easily converted into liquids, are absorbed in greater quantities, than those more permanent; hence *vapors* are absorbed more easily than gases, and liquids than ether. Hence, too, charcoal when exposed to the air, or other gases, increases in weight.*

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* The increase varies with the kind of wood from which it is made; according to the experiment of Allen and Pepys, charcoal from fire gains 13 per cent, lignum vitae 9.6 per cent.; that from

Box,	14.	Oak,	16.5
Birch,	16.3	Mahogany,	18.

The absorption is the most rapid during the first twenty-four hours; it absorbs oxygen from the air more rapidly than nitrogen.

It also absorbs the *odoriferous*, and *coloring principles* from most animal, and vegetable substances.

Exp. Pass ink through pulverized charcoal, and the color will be discharged. Red wines, rum and brandy may be rendered colorless by filtration through it. It is used extensively for *refining sugar*, and for preparing colorless crystals of citric acid, and other vegetable productions. Stagnant water, and most animal and vegetable substances, in a putrescent state, will be cleansed and purified by this substance; hence its use to purify docks, vessels, etc. Prutrescent meat is purified by rubbing it with charcoal, and generally all substances subjected to putrescence, may be preserved for a long time, by surrounding them with charcoal. In consequence of this property, it is used in medicine as an antiseptic in *putrescent diseases*. Animal charcoal is the best for these purposes, and as its efficacy depends upon its power of absorption, it should be heated to expel all the gas, before it is used, or kept in well stopped bottles as soon as prepared.

It is very combustible. It requires a strong heat to ignite it, but then it will burn for a long time, the oxygen of the air uniting with it and forming carbonic acid.* In consequence of this property, *it is one of the most useful substances in nature.*

It is the most durable substance known. Grains of wheat and rye charred in Herculaneum by the volcanic eruption, A. D. 79, were easily distinguished from each other, eighteen centuries afterward; an arrow head has been charred so as to preserve the form of the feather. The stakes driven down in the bed of the Thames, by the Britons, to prevent the army of Julius Cæsar from passing the river, were discovered about fifty years since, and were all charred to a considerable depth. They were as perfect as when driven; were made into knife handles, and *sold as antiques* at a high price. Farmers char their troughs and posts to prevent decay.

It is infusible by any degree of heat, except that from a powerful galvanic battery, and in this case there is reason to doubt, whether there is a fusion of anything but some impurities.

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* Large quantities of powdered charcoal often *ignite spontaneously*, owing doubtless to the small quantity of potassium which is generally found in connection with it.

Uses. The uses of carbon have already been stated, and are generally well known. It is one of those substances which are indispensable to the wants, to the existence of our race; and the Creator has given us, in its character and abundance, the most decisive proofs of his wisdom and benevolence.

Carbon possesses extensive powers of combination, and forms a class of substances of great and permanent utility in chemistry, the arts, and the common business of life.

Carbonic oxide. Symb. CO or $\dot{C}$. Equiv. $6.12+8=14.12$. Sp. gr. 0.9727, air = 1.

History. Discovered by Priestly by the distillation of charcoal with the oxide of zinc; but its composition was first determined by Mr. Cruickshank.

Process. The best and most convenient mode of obtaining this substance, is to put two parts of well dried chalk, pulverized, to one of iron filings into a gun-barrel, and raise the temperature to a red heat. The gas may then be collected over water; it may be obtained also, by heating the oxides of several of the metals with powdered charcoal.

Theory. Chalk is composed of carbonic acid, and lime. One equivalent of oxygen contained in the acid, goes to the iron, and converts the acid to the carbonic oxide; oxide of iron, and lime remain, or CO^2+CaO and Fe are converted into FeO, CaO, and CO.

Properties. A colorless insipid gas of an offensive odor. It is *highly inflammable*, and burns with a pale blue flame, when a lighted taper is plunged into it; but does not support combustion. A mixture of one part of oxygen, to two of the gas, *is explosive;* the result is carbonic acid. *It is destructive to animal life*; an animal immersed in it soon dies; when diluted with air, it causes fainting and giddiness.

Carbonic acid. Symb. $C+2O$, CO^2 or $\ddot{C}$. Equiv. $6.12+16=22.12$. Sp. gr. 1.5239, air = 1.

History. Discovered in 1757 by Dr. Black, who called it *fixed air.*[*] This was the first gas known, except the atmosphere, and laid the foundation of *pneumatic chemistry*.

Natural History. Carbonic acid exists very abundantly in nature, generally in combination with lime, forming the *carbonate of lime*, or marble.

Process. It is obtained by the combustion of the diamond in oxygen gas, or by burning charcoal in the air, or oxygen; but it is more easily obtained by decomposing some of the *carbonates*. Take pulverized carbonate of lime, (marble or chalk,) in a glass retort, and pour on sulphuric or hydrochloric acids, diluted with five or six parts of water, and collect over water, or in a globe-receiver, in the same manner as hypochlorous acid gas.[†] (See page 128.)

Theory. In this process, the sulphuric acid combines with the lime, forming the sulphate of lime, and liberates the carbonic acid. SO^3, CO^2+CaO are converted into SO^3+CaO and CO^2.

Properties. It is colorless, inodorous, and elastic, requiring a pressure of thirty-six atmospheres, 540 lbs., to the square inch, to condense it into a liquid—more than 1½ times as heavy as atmospheric air, and hence may be poured from one vessel to another, like water.

It is neither a combustible nor a supporter of combustion.

Exp. Into a jar of carbonic acid, let down a pendant candle. It will be extinguished as soon as it reaches the gas, or it may be poured upon the candle from a vessel. The flame does not cease from want of oxygen, since four measures of air, and one of carbonic acid, will extinguish flame; hence a positive influence is exerted upon it.

It is rapidly absorbed by water.

Exp. If a small quantity of water be agitated in a bottle containing carbonic acid gas, it will soon absorb it and acquire acid properties. Recently boiled water will absorb one vol. of the gas at the common temperature and pressure, but increases in its absorbing power in proportion to the pressure applied. It absorbs twice its vol. when the pressure is doubled; three times its vol. when the pressure is trebled, etc.

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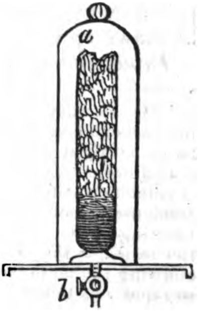
[*] Its composition was first demonstrated synthetically, by Lavoisier, who obtained it by the combustion of charcoal in oxygen gas. Smithson Tennant proved its composition analytically by passing the vapor of phosphorus over chalk, heated to redness in a glass tube.

[†] If intended to be kept long, it should be transferred from the cistern in bottles, as the water rapidly absorbs it.

Water may be acidulated with it, by employing Woulf's apparatus in the same manner as with hydrochloric acid. (See page 144.) In the common soda fountains, the water is confined in a strong brass, or copper vessel, and charged with the gas by a forcing pump. The pleasant pungent taste, and sparkling appearance of fermented liquors, soda, and seidlitz waters, and the waters of many mineral springs, are due to the carbonic acid which they hold in solution. The water saturated with it, makes a pleasant and healthful drink.

The acid escapes on exposure to air and heat. Hence all such drinks soon become insipid.

Fig. 65.



Exp. Place a tumbler of water (fig. 65.), saturated with this gas, under the receiver *a* of an air pump *b*, and exhaust the air. The gas will escape so rapidly as to present the appearance of boiling. Any of the fermented liquors will produce a similar phenomena.

If the water saturated with the acid, be rapidly congealed, the frozen water has the appearance of snow, its bulk being greatly increased by the immense number of bubbles formed by the liberated gas.

It is an acid as shown by chemical tests.

Exp. Put a piece of litmus paper into water saturated with it, and it is turned red; but by heat, or exposure to the air, the color returns, owing to the escape of the acid.

This is not the case with any other acid; the colors they form, are generally permanent unless changed by alkalies.

The best test of carbonic acid is lime water, which is rendered turbid by the gas.

Theory. Carbonic acid unites with the lime which the water holds in solution and forms the carbonate of lime, which is soluble in water, and is precipitated in fine powder. This gives to the water a milky appearance. If, however, you continue to add carbonic acid, it will dissolve the carbonate, and the water will become clear again, *carbonate of lime* being very soluble, in excess of carbonic acid.

Solidification of carbonic acid. It has lately been ascertained, that when the gaseous carbonic acid is subjected to a pressure of thirty-six atmospheres, it is condensed into a liquid, and at –85° into a solid resembling compact snow.*

Relations to animal life. Although water saturated with carbonic acid proves a healthful and invigorating drink, the free acid cannot be taken into the lungs without producing almost instant death ; in fact the glottis closes at its approach, and will not suffer it to enter. If it be diluted with air, it acts upon the system as a narcotic poison ; an animal thrown into it is usually suffocated.† Carbonic acid is heavier than the air, and hence often remains in wells and deep pits, where it is generated, and called by the miners *choak damp.* Before descending a candle should be let down, and if it will not burn, life cannot be supported. The acid may be absorbed by pouring down large quantities of water. It may be partially expelled by exploding gunpowder near the bottom; or it may be drawn up with large buckets.

Production of carbonic acid. Causes are in constant operation to form carbonic acid, and throw it off into the atmosphere. It is evolved in great quantities from the earth, from ordinary combustion, and by the respiration of animals. In the two last cases, the oxygen of the air is consumed, and carbonic acid takes its place; hence we should expect, if there were nothing to counteract this process, that the whole atmosphere would, in time, be rendered unfit to support respiration; but not more than $\frac{1}{1000}$ part of the atmosphere is carbonic acid. In places near cities, or where it is evolved from the earth, the proportion may be greater. This tendency, however, may be counteracted by the vegetable kingdom. During the daytime, plants absorb carbonic acid, decompose it, retain its carbon, and throw off its oxygen. In the night the process is reversed, oxygen is consumed, and carbonic acid is thrown off; but more of oxygen is emitted in the daytime than is consumed in the night, more carbonic acid also is consumed during the day than is given off during the night. The balance from this process is needed to meet the demands of the animal kingdom, which constantly consumes oxygen, and generates carbonic acid in the process of respiration. Thus the equilibrium of the atmosphere is preserved, and both kingdoms flourish together.

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* Mr. Faraday first condensed carbonic acid into a liquid by placing carbonate of ammonia in one end of a strong glass tube, bent twice at right angles, and sulphuric acid in the other end, which is sealed hermetically. When the acid is poured upon the ammonia, it combines with it and liberates the gas, which by the pressure is condensed ; but this process is attended with much danger, from the bursting of the tube. A safer method has been contrived by Thillorier in which the gas is condensed in a strong metallic cylinder. By allowing the liquid acid to escape through the stop-cock, it expands so rapidly as to become frozen, owing to the absorption of its sensible caloric. A reduction of temperature to –162° is said to have been produced by this means. The solid acid thus formed, is about the weight of carbonate of magnesia, perfectly white, and of a soft, spongy texture. It evaporates so rapidly that mercury and even alcohol, sp. gr. .820, are frozen. According to the experiments of Mitchell of Philadelphia, the greatest cold produced by the solid acid in the air was –109°, and under an exhausted receiver –136°. The pressure at 32o was 36 atmospheres, at 66°, 60 atmospheres, and at 86°, 72 atmospheres, or 1290 lbs. to the square inch. When obtained in a liquid form in a glass tube, it is colorless and extremely fluid. In attempting to open the tubes at one end, they uniformly burst into fragments with *violent explosions.*

† *Caution.* This gas is always produced in burning charcoal, and hence the danger and criminality of placing pans of hot coals in sleeping apartments, or in rooms not ventilated by a chimney. The acid gradually mixes with the air, causing drowsiness, and even death, before the person can escape. Every year adds new proofs, in the loss of many lives, to the folly and danger of such practices.

Exp. That carbonic acid is given off in respiration, may be shown by breathing with a quill through lime-water, which will become turbid. This fact enables us to understand the process of

Respiration. The blood, in its progress through the system, becomes filled with carbon, which gives to it a dark color. When it passes into the lungs, the air is brought in contact with it; the carbon unites with the oxygen, forming carbonic acid, which is expelled, and the blood is changed to a bright red; it is now fitted to nourish the system. Some suppose that the oxygen enters into the blood, and that the combination takes place during the course of circulation, but whichever theory be adopted, carbonic acid is thrown off, and oxygen is consumed. Hence in crowded assemblies, great quantities of this gas are formed, and as a consequence, dullness, and fainting often ensue. Hence, also, the necessity of having large public rooms well ventilated.

Dichloride of carbon. Symb. C^2Cl. Equiv. $12.24+35.42=47.66$. Was discovered by M. Julin. It occurs in small, soft, adhesive fibres, of a white color, of a peculiar odor resembling spermaceti, and is tasteless; burns with a red flame, emitting much smoke, and fumes of hydrochloric acid gas.

Protochloride of carbon. Symb. CCl. Equiv. 6.12+35.42=41.54. It is obtained by passing the vapor of perchloride of carbon through a heated glass tube, filled with fragments of rock crystal, to increase the heated surface. It is a *limpid*, *colorless* liquid, density 1.5526.

$\frac{5}{4}$ *Chloride of carbon.* Symb. C^4Cl^5. Equiv. 24.48+177.1=201.58. Discovered by Liebig, and sometimes called the *new chloride of Liebig*; obtained by boiling chloral with a solution of lime, potassa, or baryta. It is a limpid, colorless liquid, similar in odor and appearance to the oily fluid which chlorine forms with olefiant gas; density, 1.48, boils at 141° Far.

Perchloride of carbon. Symb. C^2Cl^3. 12.24+106.26=118.5. Discovered by Faraday. When olefiant gas is mixed with chlorine, combination takes place between them, and an oil-like liquid is formed, consisting of carbon, hydrogen, and chlorine. Expose this liquid, in a jar of chlorine, to the solar rays, and hydrochloric acid is set free, and the chlorine unites with the carbon.

Properties. At common temperatures, it is a colorless, transparent solid, of an aromatic odor, resembling that of camphor, fuses at 320°, and boils at 360°.

Chloro-carbonic acid. Symb. O+C+Cl. Equiv. 8+6.12+35.42=49.54. This singular compound of oxygen, chlorine, and carbon affords a somewhat unusual instance of two acidifying principles, uniting with one base to form an acid. It was discovered by Dr. Davy, who called it *Phosgene gas*. It is formed by exposing equal vols. of chlorine and carbonic oxide to the solar rays, when rapid, but silent combination takes place, and they contract to one half their volume.

Properties. A colorless gas with a strong odor, reddens litmus paper, and combines with four times its vol. of ammoniacal gas. Water, and several of the metals decompose it.

Chloral—symb. $C^9Cl^6O^4$. Equiv. 299.60—is a new compound of carbon, oxygen, and chlorine, discovered by Liebig, and prepared by the mutual action of alcohol and chlorine. It is a colorless, transparent liquid, of a penetrating, pungent odor, nearly tasteless, oily to the touch; density 1.502, and boils at 201°.

Periodide of carbon was discovered by Serullas, and is obtained by mixing an alcoholic solution of pure potassa, and of iodine. It forms crystals of a pearly lustre, sweet to the taste, and of a strong aromatic odor resembling saffron.

The *protiodide* is formed by distilling a mixture of the preceding compound with corrosive sublimate. It is a liquid of a sweet taste, and penetrating, ethereal odor.

Bromide of carbon.—Formed by mixing one part of periodide of carbon with two of bromine: two compounds are formed, the *bromide of carbon* and the *sub-bromide of iodine;* the latter is removed by a solution of caustic potassa. It is liquid at common temperatures, but crystallizes at 32° Far.; sweet to the taste, and of a penetrating, ethereal odor; distinguished from the protiodide by the vapor which it emits on exposure to heat.

Carbon and Hydrogen.

Two compounds of carbon and hydrogen have been known for some time, but of late the number has been increased to at least twelve.

Dicarburet of Hydrogen. Symb. $C+2H$ or CH^2. Equiv. $6.12+2=8.12$. Sp. gr. 0.5593, air $=1$.

History. This substance is generally known under the name of *light carburetted hydrogen.* The names *heavy inflammable air*, the *inflammable air of marshes*, and *hydrocarburet*, have also been applied to it; but taking carbon as the electro-negative element, it is more agreeable with the principles of nomenclature to call it a *dicarburet of hydrogen.* Dalton first ascertained its real nature, but it was subsequently examined by Davy, Thompson and Henry.

Process. This gas is formed naturally by the decomposition of vegetable matter in marshes. It may be obtained by inverting a receiver in almost any stagnant pool, and stirring the sediment at the bottom. In this state it contains one twentieth part of carbonic acid, and one fifteenth of nitrogen; the former may be removed by lime-water, or pure potassa. This is the best mode to obtain the pure gas.

It is formed also by the distillation of mineral coal, containing carbonic acid and olefiant gas; the former may be removed by lime-water, the latter by chlorine.

Properties. Colorless, tasteless, and nearly inodorous. Water absorbs $\frac{1}{60}$ of its vol. It extinguishes all burning bodies, but is highly combustible. It burns in a jet with a yellow flame brighter than hydrogen; destructive to animal life when respired; partially decomposed by a very intense heat.

Exp. Mixed with rather more than twice its vol. of oxygen, it is explosive; exactly two volumes of oxygen are consumed, and the products are carbonic acid, and water.

Exp. Mixed with chlorine, and exposed to the solar light, it is decomposed, and hydrochloric and carbonic acids are formed; though the products will depend upon the quantity of chlorine.

Olefiant gas or $\frac{2}{2}$ carburet of hydrogen. Symb. 2C+2H. Equiv. 12.24+2=14.24. Sp. gr. 0.9808, air =1.

History. Discovered in 1796 by some associated Dutch chemists, who called it ***olefiant gas*** from its forming an oil-like liquid with chlorine. It has been called ***hyduret of carbon***, ***bicarburetted*** or ***percarburetted hydrogen***, but ***$\frac{2}{2}$ carburet of hydrogen*** accurately designates its composition, and is, on this account, preferable.

Process. Mix in a large retort 1 measure of alcohol with 2 of concentrated sulphuric acid, and apply the heat of a spirit-lamp. The mixture soon turns black, and rises up in the retort; the gas is rapidly disengaged, and may be collected over water or mercury; carbonic and sulphuric acids are formed during the process, and may be separated by pure potassa or lime-water.

Theory. Alcohol is a compound of olefiant gas and water. The sulphuric acid unites with the water, and the gas is evolved. C^2H^3O and SO^3 are converted into SO^3, HO and C^2H^2. At the commencement of the process *ether* is formed, which differs from alcohol by having 2 equiv. of olefiant gas combined with water, while alcohol has but one. The ether is condensed in the cistern.

Properties. It is a colorless, tasteless gas, and has scarcely any odor when pure. Water absorbs $\frac{1}{8}$ of its volume. It extinguishes a lighted taper when immersed in it, and therefore does not support respiration. It burns with a clear white light.

Mixed with oxygen it is highly explosive.

Exp. Mixed with oxygen in the proportions of 1 vol. of the gas to 3 of oxygen, and kindled by flame, or the electric spark, it explodes with great violence. This may be shown by the gas-pistol. There is, however, much danger of bursting the pistol; glass vessels should not be employed to explode it.

Exp. Bubbles of the mixture may be passed up through the water of the cistern, and exploded upon the surface; but care should be taken that the fire is not communicated to the vessel containing the mixture, through the bubbles as they rise.

It is decomposed by heat. By passing it through a porcelain tube at a low red heat, charcoal is deposited, and the bicarburet evolved, which, at a white heat, is also decomposed. It is also resolved into hydrogen and carbon by a succession of electric shocks.

Action of Chlorine. When two volumes of chlorine and one of olefiant gas are mixed and ignited, they burn rapidly and form hydrochloric acid, while the carbon is deposited; but if the gases remain at rest, they slowly combine and form an oily liquid of a yellow color, called *chloride of hydrocarbon.*

$\frac{4}{4}$ *Carburet of hydrogen, etherine.* Symb. $4C+4H$. Equiv. $24.48+4=28.48$. Sp. gr. 0.627, water = 1. Was first obtained by Faraday in the process of compressing oil gas into strong copper globes, for the supply of portable gas. It is a highly volatile liquid, the lightest liquid body known. At 60° it is exceedingly combustible, and burns with a brilliant flame.

$\frac{3}{6}$ *Carburet of hydrogen*—Symb. $6C+3H$. Equiv. $36.72+3=39.72$. Sp. gr. 0.85—was obtained by Faraday from the same oil gas liquid which yielded etherine. At common temperatures it is a colorless transparent liquid, smells like oil gas, with a slight odor of almonds. It is highly combustible, and forms with oxygen a powerful detonating mixture.

Parraffine is a compound of carbon and hydrogen obtained by the distillation of the petroleum of Rangoon, and also by that of tar, derived from beech wood. It is a fatty substance without taste or odor, and burns with a pure, white flame.

Eupione differs from the preceding compound only in containing a smaller portion of carbon. It is obtained by distillation of the tar derived from bones or horns. It is a tasteless, inodorous liquid, similar to oils, but as limpid as alcohol.

Naphtha—Symb. $6C+5H$. Eq. $36.72+5=41.72$. Sp. gr. 0.753—is obtained from coal tar by distillation. It is a volatile, limpid liquid, of a strong, peculiar odor, and generally of a light yellow color. It is *very inflammable*, burning with a white flame and much smoke. It is used to preserve potassium.

Naphthaline—Symb. $C^{10}H^{4}$. Equiv. $61.2+4=65.2$—is obtained in the same manner as the preceding compound. It is a white crystalline solid, heavier than water, has an aromatic pungent taste, and faintly aromatic odor. With sulphuric acid it forms a compound, first described by Faraday in 1826, under the name of *sulpho-naphthalic acid*, which has a bitter taste and acid properties.

Paranaphthaline—Symb. $C^{15}H^{6}$. Equiv. $91.8+6=97.8$—is allied to the preceding, and obtained from coal tar.

Idrialine is also similar, and obtained from a mineral in the quicksilver mines at Idria in Carniola.

Champhene and *Citrene.* Symb. $C^{10}H^8$. Equiv. $61.2+8=69.2$. Champhene is the basis of camphor; *colorless*, volatile, and inflammable; odor like the oil of turpentine. *Citrene* is almost the sole ingredient of the oil of lemons.

Gas lights.

History. The gas, now so generally employed for the purpose of lighting cities, is probably a mixture of several of the preceding substances, composed mostly, however, of *olefiant gas.* This gas was first employed for the purposes of illumination by Dr. Clayton in 1739, but was soon given up for more than sixty years. The subject was investigated about fifty years since by Mr. Murdock; and since that time gas lights have come into general use, both in Europe and America. The gas was obtained chiefly from the distillation of coal, but that obtained from oil (spermaceti the best) is much purer, and possesses a greater illuminating power. Gas from rosin is about equal to that from oil.

Process. When oil is used, several large cylindrical cast iron retorts are laid across a furnace, and partially filled with brick and bits of iron to increase the heated surface. The oil is contained in a reservoir, and conveyed to the retorts by separate tubes. When the retorts are heated to the proper temperature, the oil is admitted by a stop-cock in a small stream, so that it is immediately decomposed, and the gas passes out of the retorts by other tubes, running into a large one which conveys it to the gasometer.*

When coal is used, the process is similar; gas needs to be purified by passing it through lime-water to deprive it of carbonic acid and other impurities which give it a very disagreeable odor; 112 pounds of coal yield from 450 to 500 cubic feet of gas; sp. gr. 0.450 to 0.700; and $\frac{1}{2}$ cubic foot of gas per hour is equivalent to a candle, six to the pound, burning during the same time. But oil gas, though much more expensive, possesses nearly twice the illuminating power. According to Henry, it requires vessels and tubes of but half the size. 20 cubic feet of coal gas, or 10 of oil gas, is equal to a pound of tallow.*

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* The gasometer is made of iron, in some cases 40 feet in diameter and 20 feet high, containing 20,000 cubic feet. This is immersed in a vat containing water, and the air permitted to escape by a valve in the top. When it is filled with water, the gas from the large pipe is conducted to the bottom, and passes up through the water into the gasometer, which rises as fast as it is filled. The gas is now conveyed in a cast-iron pipe, laid under ground, to which small pipes are attached, branching off to every part of the city where it is wanted.

Portable gas. In consequence of the greater cheapness of gas lights, as compared with candles and oil, it seemed desirable to contrive some method by which it could be made portable. This object has been effected by what are called *portable lamps.* The gas, by means of a forcing pump, is compressed into strong brass globes, and ignited as it escapes through an aperture which is furnished with a stop-cock to regulate the quantity. These can be carried about like common oil lamps. For this purpose, the gas obtained from rosin is employed.

Fire damp. This term is applied to several gaseous compounds of carbon and hydrogen, which are produced in the mines of bituminous coal. It is mostly *light carburetted* hydrogen, and is produced by the decomposition of the water by the coal. It issues from various parts of the coal beds, in such quantities as to render the whole atmosphere of the mines explosive, and often irrespirable. Hence the miners were exposed to frequent explosion and to suffocation. Many explosions have occurred in the coal mines of England: the older mines extend miles under the ground, and, in some cases, are several hundred feet deep. As the gasses are lighter than the air, they rise and mingle with the air near the top, and gradually descend until they reach the miner's lamp, when the whole is instantly exploded.† In consequence of the great expense of human life, and the constant fear of the miners, Sir H. Davy undertook the investigation of the subject for the purpose of inventing some means of safety. He went with the miners into the region of the fire-damp, obtained specimens of the gas, and subjected it to chemical examination. He found that the most explosive mixture was 1 part of gas to 7 or 8 of air; 5 or 6 vols. of air would explode but feebly, and above 14 vols. of air to 1 of gas did not explode at all. It was also found, that it required the heat of flame to explode it. Iron at a red heat, and even at a white heat, would not affect it. But the fact which led immediately to the invention of the *safety lamp*, had been observed by Dr. Wollaston, that "*an explosive mixture cannot be kindled in a glass tube so narrow as $\frac{1}{7}$ of an inch in diameter.*" It was also noticed, that the mixture could not be exploded through fine wire sieves, or gauze wire, which acts on the same principle as longer tubes.

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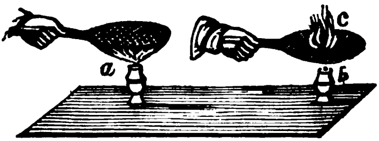
* Coal gas costs about two thirds as much as oil gas, and about one fifth as much as spermaceti candles.

† In 1812, an explosion occurred in Felling colony in Northumberland, by which ninety-two men lost their lives. The explosion was heard three or four miles; thirty-two persons only were saved alive. In 1815, a similar occurrence happened at Durham, and destroyed fifty-seven persons—and in another, twenty-two lost their lives.

Exp. Place the gauze wire *a* (fig. 66.) over a jet of the gas, the flame may be pressed down, and will not pass through the wire.

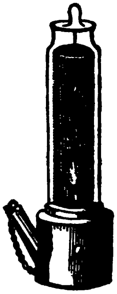
Exp. Let a stream of the gas pass through the wire *c*, the gas may be ignited on the top of the wire, but will not communicate through it to the tube *b*. The same is true of flame by whatever substance it is produced. The wire conducts off the heat, so that they do not gain the temperature requisite to ignite the gas.

Fig. 66.



Safety lamp. This consists simply of a common lamp *a* (fig. 67.) with a gauze wire *b* surrounding the flame. The wire should have at least 625 apertures to the square inch. Furnished with this lamp, the miners can enter the mines in perfect safety from explosion, but are exposed to suffocation, when there is not sufficient oxygen in the mines to support the combustion of the oil.

Fig. 67.



Carbon and Nitrogen.

Bicarburet of nitrogen, or ***cyanogen***. Symb. NC^2 or Cy. Equiv. $14.15+12.24=26.39$. Sp. gr. 1.804, air = 1.

History. This gas was discovered in 1815, by Gay Lussac. It is sometimes called ***nituret of carbon***, but ***bicarburet of nitrogen*** expresses definitely its composition.

Process. It is obtained from the bicyanuret of mercury, by heating the salt in a small glass retort, with a spirit lamp. The retort should be covered with lute to prevent its melting. At a red heat, it is resolved into its elements. The cyanogen passes over in the form of a gas, and the mercury is sublimed and remains in the neck of the retort in small globules. Collect over mercury, or air.

Properties. This gas is colorless, with a strong, pungent odor; not a supporter of combustion, but burns itself with a beautiful purple flame, resembling the peach blossom. Water, at the common temperature and pressure, absorbs 4½ times its vol., and alcohol 25 times its volume. At the temperature of 45° and under a pressure of 3.6 atmospheres it is condensed into a limpid liquid, but resumes the gaseous state when the pressure is removed. The most remarkable chemical property of this substance is, that it acts like a simple body in most of its combinations, forming substances consisting of *three* elementary bodies, analogous to those formed in other cases by *two.*

Cyanic acid—Symb. $Cy+O$. Equiv. $26.39+8=34.39$—may be obtained by exposing cyanuric acid to a dull red heat. It has a penetrating odor, pungent, and caustic to the skin, producing great irritation of the eyes; very volatile, giving off an inflammable vapor.

Fulminic acid. This is isomeric with the preceding, i. e. identical in composition, but possessed of different properties. It is called *fulminic* because its compounds of mercury and silver are highly explosive.

Cyanuric acid.—Symb. $Cy^3O^6H^3$. Equiv. 130.17,—was obtained by Serullas by gently boiling bichloride of cyanogen in water: cyanuric and hydrochloric acids are the results. The hydrochloric is removed by evaporation, and the cyanuric deposited on cooling, in oblique rhomboidal crystals. The crystals are further purified by solution and evaporation.

Paracyanuric acid is identical in composition with the preceding, but different in properties; it results from the spontaneous decomposition of hydrous cyanic acid.

Chloride of cyanogen. Symb. $Cy+Cl$. Eq. 61.81. First obtained in a pure state by Serullas in 1829, by exposing bicyanuret of mercury in powder, and moistened with chlorine gas in a well stopped vial. It congeals at zero in needle-shaped crystals; is liquid between 5° and 10°, but above this it is a colorless gas, of a very offensive odor, irritating to the eyes, corrosive to the skin, and highly injurious to animal life.

Bichloride of cyanogen. Symb. Cy+2Cl. Eq. 97.23. Discovered also by Serullas, by putting 155 grains of pure hydrocyanic acid into a bottle containing sixty cubic inches of dry chlorine, and exposing it to the solar rays. The acid is vaporized, and in the course of a few hours, a colorless liquid is formed on the surface of the bottle, gradually growing thicker, until, in the space of twenty-four hours, it sets into a white solid with shining crystals. This is the *bichloride of cyanogen.* It is exceedingly poisonous, caustic to the taste, and penetrating odor similar to the chloride.

Bromide of cyanogen is similar to the preceding.

Hydro-cyanic acid, or *Prussic acid.* Symb. Cy+H. Eq. 26.39+1=27.39. Was discovered by Scheele in 1782. Berthollet afterwards ascertained that it was a compound of carbon, nitrogen, and hydrogen; but it was first procured in a pure state by Gay Lussac.

Process. The best process is that of Vanquelin. Fill a narrow tube placed horizontally, with fragments of bicyanuret of mercury, and then pass a current of dry hydrosulphuric acid gas very slowly through it. Double decomposition ensues as soon as the gas comes in contact with the bicyanuret and hydro-cyanic acid, and bisulphate of mercury are formed. When the bicyanuret becomes black, the acid is expelled by a gentle heat, and collected in a receiver surrounded with ice.

Properties. It is a limpid, colorless liquid of a strong, but agreeable odor, similar to that of peach blossoms. It excites at first a sensation of coolness on the tongue, which is soon followed by heat, but when diluted, it has the flavor of bitter almonds, exceedingly volatile, boils at 79°, and congeals at zero; unites with alcohol and water in all proportions, but possesses very feeble acid properties.

It is a most virulent poison. A single drop, if placed on the tongue of a dog, causes instant death. A girl swallowed a small quantity of it diluted with alcohol, and fell instantly, as if struck with lightning, and died in two minutes.

A professor of Vienna, put drops upon his arm, and was deprived of life in a few minutes. But though a most potent poison in its pure state, when much diluted, it has been employed as a medicine in cases of consumption, with beneficial effects. This, like many other violent poisons, cannot be employed for criminal purposes, without the almost certain risk of being discovered. It exists in the laurel, peach, and in beef-steak.

SECT. 8. SULPHUR.

Symb. S. Equiv. { By vol. 16.66. / " wgt. 16.1. Sp. gr. { 6.6558 Air = 1. / 1.99 Water = 1.

Sulphur has been known from the remotest antiquity.

Natural History. It exists in nature, in a pure state, in the vicinity of volcanoes. It collects in the craters, either in fine powder, or in crystalline solids; but it exists more abundantly in combination with the metals, forming the sulphurets of iron, copper, lead, silver, etc. from which it may be sublimed by heat, but is not quite pure. It is found also in many mineral waters; in many minerals, such as gypsum, sulphate of strontia, etc.; in all animals, and some plants.

Process. The sulphur of commerce exists in two states; in rools, called *rool brimstone*, and in fine powder called *flowers of sulphur*, but the two varieties are readily resolved into each other by the application of heat.

Exp. Heat a brick or small iron cup to nearly a red heat. Place upon it rool brimstone, and invert over it a bell-glass receiver; the sulphur will *sublime*,* i. e. pass into a fine powder like vapor, and collect on the sides of the vessel.

Properties. Sulphur is a brittle solid, of a lemon yellow color, nearly tasteless, and inodorous except when rubbed or heated. It is a *non-conductor* of electricity, but becomes *negatively electrified* by friction; fuses at 216°; possesses the highest degree of fluidity between 230° and 280°, and is of an amber color; at 320° it begins to thicken, acquiring a red tint; between 428° and 482°, it is so tenacious as to remain in the vessel when inverted, but from 482° to its boiling point, it grows fluid again, and sublimes rapidly from 550° to 600° Far.

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* This may serve to illustrate the process of *sublimation* as applied to other substances.

When cooled from the several temperatures above named, it possesses different degrees of consistency. Cooled suddenly from the most fluid state, it is hard and brittle; but if plunged into cold water between the temperatures of 320° and 482°, it is soft, and may be drawn out like wax; cooled from the boiling point, it is of a deep red brown color, very soft and transparent. It is prepared in this way for taking seals. The native crystals are octohedrons, with rhombic bases; those formed artificially, occur in oblique rhombic prisms.

Exp. Melt a few lbs. of sulphur in an earthen crucible, and when it is partially cooled pierce the crust so that the fluid parts may flow out; on breaking the mass when cooled, the interior will exhibit a cluster of beautiful crystals.

Sulphur is soluble in boiling oil of turpentine, which is a test of its purity.

Impurities. It contains some hydrogen in its purest state, but the more common ingredients are earthy substances and arsenic, the latter is tested by ammonia.

Uses. Employed extensively in the manafacture of gunpowder, for seals, medallions, and as a cement for iron. Used in medicine, for the diseases of the skin, humors, etc. The *milk of sulphur*, which is sulphur combined with water, and precipitated from some of its alkaline solutions by an acid, occurs in a grey powder, and is sometimes used in medicine.

Hyposulphurous acid. Symb. $2S+2O$. Eq. $32.2+16=48.2$. It is difficult to procure this in a pure state. It may be formed by digesting sulphur in a solution of any *sulphite.* It is distinguished by uniting with the oxide of silver, which separates the acid from soda.

Sulphurous acid. Symb. $S+2O$ or SO^2. Eq. $16.1+16=32.1$. Sp. gr. 2.2117, air=1.

History. Sulphurous acid appears to have been known from an early period. Stahl first pointed it out as a distinct substance, but its discovery in a pure state, was made by Priestly in 1774, and accurately analyzed since, by Gay Lussac, and Berzelius. It exists in nature in the vicinity of volcanoes, and issues from the fissures in the craters, and from the lava, often in immense quantities.

Process. Burn sulphur in common air, or in dry oxygen gas over mercury; but the best method is to put two parts of mercury and three of sulphuric acid into a retort, and apply the heat of a lamp, and collect over mercury.

Theory. The sulphuric acid has 3 equiv. of oxygen, one of which unites with the mercury, forming the oxide of mercury, which combines with some undecomposed sulphuric acid, and forms the sulphate of mercury which remains in the retort, and the sulphurous acid comes over in the gaseous state. The gas is heavier than the air, and can be collected in a manner described on page 123, fig. 51.

Properties. A transparent, colorless gas, sour to the taste, and *pungent suffocating odor*, by which it is distinguished from all other gases; extinguishes burning bodies, but is not combustible.

It is irrespirable and fatal to animal life. When largely diluted with air, it excites coughing, and uneasiness about the chest; when perfectly pure, it excites spasms of the glottis, which prevents its introduction into the lungs—of course, an animal confined in it, is instantly suffocated. It reddens vegetable colors, and then discharges them.

Exp. Place a rose over an ignited sulphur match in the open air, and it will turn white; hence it is used for bleaching straw, silk, and for removing fruit-stains from woollen cloths, etc.

It has a strong attraction for water and oxygen. Water absorbs it so rapidly, that if a jar of the gas be inverted over it, the atmosphere will force the water into the jar with great violence; recently boiled water absorbs 33 times its vol.

Sulphurous acid will remain with dry oxygen without change, but if water be present, it combines with oxygen, and forms sulphuric acid. It instantly decomposes those oxides, the metals of which have a weak affinity for oxygen, such as those of gold, platinum, and mercury. Nitric acid yields to it one proportion of oxygen, and converts it to sulphuric acid.

Liquid sulphurous acid. It becomes liquid by the pressure of two atmospheres, and even by surrounding it with a freezing mixture. In this state it is *anhydrous*, a little heavier than water; sp. gr. 1.45, and boils at 14° Far. By its evaporation, it produces so intense a degree of cold, that mercury may be frozen, and several of the gases rendered liquid.

It may be obtained in the solid form in crystals containing water, by passing the moist gas through a receiver, cooled from 50° to 14° Far.

Hyposulphuric acid. Symb. $2S+5O$. Equiv. $32.2+40=72.2$. This acid was discovered in 1819, by Welter and Gay Lussac.

Process. It may be formed by passing sulphurous acid gas through water containing peroxide of manganese. By the interchange of elements, the sulphate of the peroxide, and the hyposulphate of the protoxide of manganese are formed, the latter remains in solution. The manganese is thrown down by pure baryta, and the hyposulphate of baryta obtained, which crystallizes by evaporation, and is then decomposed by sulphuric acid, by which the sulphate of baryta is precipitated, and hyposulphuric acid remains in solution.

Properties. Colorless, inodorous, sour to the taste, reddens litmus, and cannot be wholly freed from water.

Sulphuric acid. Symb. $S+3O, SO^3$ or $\dddot{S}$. Equiv. $16.1+24=40.1$. Sulphuric acid was discovered by Basil Valentine, near the close of the fifteenth century. It is commonly called *oil of vitriol*, because it was first obtained by the distillation of *green vitriol* (sulphate of iron or copperas). It exists in nature abundantly, in the sulphate of lime (gypsum).

Process. Anhydrous sulphuric acid may be obtained from the hydrous acid, manufactured at Nordhausen in Germany, from the *proto-sulphate of iron*, and called *fuming sulphuric* *acid.* But the best method is that of Professor Mosander of Stockholm. Saturate the oxide of antimony with excess of sulphuric acid, and then by a slow heat, drive off the excess of acid, when the salt will crystallize as a dry sulphate of antimony. Expose this salt to a dull red heat in a retort, and the anhydrous acid will be driven off, and may be collected in a dry receiver, surrounded with ice.

Properties. In this state the acid has some peculiar properties. It is a white opaque solid, fuses at 66° Far., sp. gr. 1.99, boils between 104° and 122°, forming a transparent vapor; has *a powerful affinity for water*, so that on exposing it to the air, it flies off in white fumes.

Hydrous sulphuric acid, which is the ordinary acid of commerce, may be obtained by several modes.

Exp. Burn a mixture of 8 parts of sulphur to 1 of nitre in a vessel of oxygen gas containing a vegetable infusion; the acid will be absorbed by the water, and change the infusion red. But the process for manufacturing this acid in the arts, is done in chambers *lined with sheet lead.** Eight parts of sulphur to 1 of nitre, coarsely bruised and mixed together, are put upon iron plates, 1 lb. to 300 cubic feet of air. The mixture is ignited by a hot iron, and the door closed. Water, to the depth of 6 inches covers the floor, and absorbs the acid as fast as formed. The room is then ventilated, and the process repeated every four hours, until the water is sufficiently acid; or by an improvement in the structure of the room, the sulphur is burned in a separate room, and the air admitted continually carries the acid vapor into the chamber where it is condensed by the water. This acidulated water is then drawn off and concentrated by heat, in leaden boilers, until it is of the specific gravity 1.450, and the concentration is finished in glass or platinum dishes placed in sand baths.

Theory. By the combustion two gases are formed, sulphurous acid from the sulphur, and binoxide of nitrogen from the nitre. The latter combines with the oxygen of the air, and is converted into the nitrous acid. The sulphurous and nitrous acids then combine with the watery vapor and form a crystalline solid, composed of sulphuric acid, hyponitrous acid, and water. When this solid drops into the water, it is instantly decomposed, the sulphuric acid is retained in the water, and nitrous acid and binoxide of nitrogen escape. The nitrous acid thus set free, as well as that formed by the binoxide and oxygen of the air, again combine with the moist sulphurous acid and form the solid which sinks to the water, and is decomposed again. This process continues, until the whole is converted into sulphuric acid, and absorbed by the water.

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* The usual size of the chamber is 20 feet long, and 12 wide; but in one establishment in England, the chamber is 120 feet by 40, and 20 high, containing 96,000 cubic feet.

Properties. *Hydrous sulphuric acid* when pure, is an oily, limpid liquid, colorless, inodorous, intensely sour and corrosive; destroys, by the aid of heat, all animal and vegetable bodies, with the deposition of charcoal, and formation of water; hence the acid often attains a *brown tinge* by charring substances which accidentally fall into it; boils at 620° Far., freezes at –15°. When its specific gravity is 1.78, it congeals above 32° and remains solid up to 45°; but when mixed with twice its weight of water, it congeals at –36°.

It has a powerful affinity for water. It combines with the water of the air, even at boiling temperatures, so powerfully that its greatest concentration can be effected only by glass or platinum retorts with narrow mouths.

Exp. 4 parts of sulphuric acid and 1 of water, each at 50°, when poured together, have a temperature of 300°. The heat is occasioned by the diminution of bulk, by which the insensible caloric becomes free.

Exp. 2 parts of acid and 3 of snow form a mixture which will freeze water, and the thermometer will sink even to –23°. The cold results from its affinity for water; it dissolves the snow to obtain it; and the heat necessary to render the water liquid is absorbed from the acid and the snow, and passes into an insensible state.

Exp. 1 part of snow to 3 of acid will produce a heating mixture, because the condensation developes more heat than is required to melt the snow.

The decomposition of sulphuric acid is effected by heat, and by the non-metallic combustibles.

Exp. Pass hydrogen gas and sulphuric acid through a red hot porcelain tube.

Exp. Heat this acid with charcoal, or put into it vegetable substances.

Exp. Expose the acid to the galvanic battery, the sulphur will appear at the negative, and the oxygen at the positive pole. Its sp. gr. never exceeds 1.850.

Its strength is tested by its specific gravity, and by the quantity required to saturate a given portion of an alkali. 100 grains of the carbonate of soda will neutralize 92 of pure sulphuric acid. It may be detected in any solution by the chloride of barium, by which a white insoluble solid is precipitated, the sulphate of baryta.

It is one of the most powerful acids, reddens the vegetable infusions, unites with bases, and forms salts.

It is a most violent poison. The best antidote is dry magnesia.

Uses. It is one of the principal acids of chemistry and of the arts, in which greater quantities are employed than of any acid ; for the formation of most of the other acids ; for the preparation of soda from salt, of alum from sulphate of iron ; for obtaining chlorine and other gases ; for dissolving indigo for dyes ; and used in medicine as a tonic.

Dichloride of sulphur—Symb. $2S+Cl$. Eq. 67.62. Sp. gr. 1.687—was discovered by Dr. Thompson in 1804. *Prepared* by passing a current of chlorine gas over flowers of sulphur, gently heated, till nearly all the sulphur disappears. The dichloride is then obtained by distillation in the form of a reddish liquid.

Iodide of sulphur. First described by Gay Lussac. Formed by heating four parts of iodine with one of sulphur. A dark colored substance, easily decomposed by heat.

Bromide of Sulphur is obtained by pouring bromine on sublimed sulphur. The product is an oily liquid of a reddish tint—odor resembles the dichloride of sulphur.

Sulphur and Hydrogen.

Hydrosulphuric acid. Symb. SH. Equiv. $16.1+1=17.1$. Equiv. vol. 100. Sp. gr. 1.1782, air = 1. This substance was discovered by Scheele in 1777, and has been variously named, *sulphuretted hydrogen*, and *hydrothionic acid.*

Process. It may be obtained from the sulphurets of the metals. The one generally employed is the *proto-sulphuret of iron,* which is a native product, but can be prepared by heating 2 parts of iron filings with 1½ of suphur to a red heat, in a covered crucible; upon this, in a retort, pour dilute sulphuric acid, apply gentle heat, and collect over water. *Sesqui-sulphuret of antimony,* treated in the same manner with hydrochloric acid, will yield a purer gas; the former contains a little iron and hydrogen.

Theory. The oxygen of the water unites with the iron and its hydrogen with the sulphur, and the sulphuric acid unites with the oxide of iron; the products are *hydrosulphuric acid,* and *sulphate of the protoxide of iron.* FeS, SO^3 and HO are converted into $SO^3 +$ FeO, and SH.

Properties. It is a colorless gas, but has an *excessively offensive taste and odor;* it is this gas which gives the odor to putrescent eggs, sewers, and the waters of sulphurous springs. It *extinguishes* burning bodies, but *burns* with a pale blue flame; forms an *explosive mixture* with oxygen, and is *so destructive to animal life* that $\frac{1}{1500}$ part of this gas in air destroys small birds; $\frac{1}{800}$ part killed a middle-sized dog, and $\frac{1}{250}$ part a horse. If placed on the cutaneous surface of animals, it will prove fatal to them. Reddens litmus feebly, but unites with bases and forms salts.

Water absorbs 3 vols. of the gas, and forms a colorless liquid, similar to the gas in taste and odor. This water is a *test of the metals.* Nitric acid will cause a precipitate of sulphur—and if poured into a bottle of the gas, a blue flame will pervade the vessel, and sulphur and nitrous acid fumes be produced. If exposed to the air, it deposits its sulphur on the surface of the vessel, but it is readily decomposed by metals in solution; the sulphur combines with the metal, and the hydrogen is liberated.

It is also decomposed by *chlorine* and *iodine,* because of their great affinity for hydrogen. Hence *chloride of lime* is used to purify places rendered noxious by this gas. It is partially decomposed by heat, in a porcelain tube.

Liquid hydrosulphuric acid. Mr. Faraday succeeded in liquefying the gas. Under a pressure of 17 atmospheres, it is colorless, limpid, and excessively fluid; compared with it, ether appears tenacious and oily. On breaking a tube under water, it rushed out violently, and assumed the gaseous state.

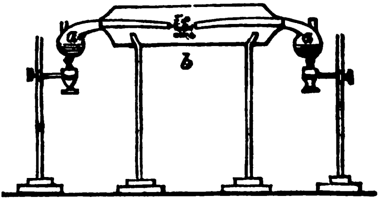
Test. The best test of this gas is carbonate of lead. 1 part of the gas mixed with 20,000 of air will give a brown stain to a surface whitened with the lead. Hence persons who use preparations of lead to improve their beauty, on coming into the vicinity of this gas, often change their color.

Exp. Write on paper with any of the salts of lead in solution, and pass a stream of the gas over it, the writing will instantly appear.

Uses. In medicine for cutaneous eruptions, in the laboratory as a test of metals.

Production of sulphur in volcanoes by the meeting of sulphurous and hydrosulphuric acids. These acids are generated in volcanoes, and as they meet are decomposed, and sulphur is deposited. This may be shown in the following manner.

Fig. 68.



Let two small retorts *aa* (fig. 68.) pass into a globe-receiver *b*, so that their mouths shall nearly touch each other. Put the materials for sulphurous acid into one, and for hydrosulphuric acid in the other, and apply heat; as the two gases meet in the receiver, they will be decomposed, and the sulphur will be deposited upon the interior surface, in fine powder.

Hydrosulphurous acid. Symb. $2S+H$. Equiv. 33 2. Discovered by Scheele, who called it *super-sulphuretted hydrogen*. The names *hydrothionous acid*, *per* or *bisulphuretted hydrogen*, and *persulphuret of hydrogen*, have also been applied to it.

It is similar in taste and odor to *hydrosulphuric acid*, but not so powerful; semi-fluid, inflammable, and easily decomposed by heat into sulphur and hydrosulphuric acid.

Sulphur and Carbon.

Bisulphuret of carbon, or *alcohol of sulphur*, *carbo-sulphuric acid*. Discovered accidentally by professor Lampadius in 1776, but its true nature was first pointed out by Clement and Desormes. It is obtained by heating, in a close vessel, the native bisulphuret of iron (*iron pyrites*) with one fifth of its weight of dry charcoal. "The compound, as it is formed, should be conducted by means of a glass tube into a vessel of cold water, at the bottom of which it is collected. To free it from moisture and adhering sulphur, it should be distilled at a low temperature, in contact with chloride of calcium —T.

Properties. A transparent, colorless liquid, remarkable for its high refractive power, acid, pungent and somewhat aromatic taste, and fetid odor; specific gravity 1.272; exceedingly volatile; boils at 110°; *very inflammable*, and burns with a pale blue flame. With oxygen, its vapor forms an explosive mixture; with binoxide of nitrogen, it forms a mixture which burns with dazzling brilliancy; dissolves in alcohol and ether, and is precipitated by water; *dissolves* phosphorus, sulphur and iodine, giving to a solution of the latter a beautiful pink color. It is decomposed by chlorine.

Cyanogen and Sulphur.

Sulphuret of cyanogen was discovered in 1828, by M Lassaigne, by the action of bicyanuret of mercury, in fine powder, upon half its weight of bichloride of sulphur, confined in a small glass globe, and exposed for two or three weeks to daylight. A small quantity of crystals, biting to the tongue, and of a penetrating odor, collect in the upper part of the vessel, which form red-colored compounds, with per salts of iron.

Bisulphuret of cyanogen—Symb. $2S+Cy$—was discovered by Liebig, by exposing fused sulpho-cyanuret of potassium to a current of dry chlorine gas—it forms a dry yellow powder.

Hydro-sulpho-cyanic acid. Symb. S^2CyH. Equiv. 59.59. Discovered in 1808, by Mr. Porritt, who ascertained it to be a compound of sulphur, carbon, hydrogen and nitrogen. It is sometimes called *sulpho-cyanic acid*, and may be formed by suspending sulpho-cyanuret of silver, or mercury in water, and by transmitting through it a current of hydrosulphuric acid gas; sulphuret of silver or mercury, and hydrosulpho-cyanic acid are generated; filter the solution, and expel the excess of gas by heat.

Properties. A liquid either colorless, or a shade of pink, odor resembling vinegar; sp. gr. 1.002, boils at 216.5°, crystallizes in six-sided prisms at 45.5° Far. Acid to the taste, and by the chemical tests, unites with alkalies.

Test of its presence. A salt of the peroxide of iron, to which it gives a deep blood-red solution; decomposed by exposure to the air, and by chloric or nitric acid.

Cyano-hydro-sulphuric acid—Symb. S^2CyH^2. Eq. 60.59—may be obtained by passing a current of hydrosulphuric acid through a saturated solution of cyanogen in alcohol. The liquid acquires a reddish-brown tint, and numerous small crystals of an orange-red color are generated. It is considered by Liebig to be similar in composition to the preceding, but to have one equiv. more of hydrogen.

SECT. 9. PHOSPHORUS.

Symb. P.	Equiv.	By vol. 25.	Sp. Gr.	1.77,	Water = 1.
		" wgt. 15.7.		4.3261,	Air = 1.

History. Phosphorus received its name from the property of shining in the dark.*

It was discovered by Brandt, an alchemist of Hamburg, in 1660. It was formerly obtained from urine, but the process of obtaining it was for a long time kept secret, and small quantities only were obtained. Scheele obtained it from bones, and invented the method now generally employed. It exists in the bones of all animals, in the state of *phosphate of lime.* A middle sized man has about one pound of phosphorus in his bones.

Process. The bones are calcined in an open fire, reduced to a fine powder, and digested for a few days with one half their weight of sulphuric acid, with sufficient water to give them the consistency of paste. The phosphate of lime is decomposed, and the sparingly soluble sulphate, and soluble super-phosphate of lime are generated. The latter is then dissolved in warm water, filtered and evaporated to the consistency of syrup.

It is then mixed with ¼ part of charcoal in an earthen retort lined with clay, heated in a furnace to a high temperature, when the vapor of the phosphorus comes over, and is conducted by a tube into a bowl of water, where it is condensed into a reddish-brown solid. This is then fused in hot water and distilled in hydrogen, or passed through chamois leather.

Properties. When pure, it is transparent and nearly colorless, or of a wax color; easily cut with a knife, and the surface has a waxy texture; fuses at 108°, and at 550° is converted into vapor; soluble by the aid of heat in naptha, in fixed and volatile oils, and in the chloride of sulphur, sulphuret of carbon, and sulphuret of phosphorus. On cooling a solution of the latter, it crystallizes in dodecahedrons.

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* φῶς light, and φέρειν to carry,

It is very inflammable. At common temperatures, it combines slowly with the oxygen of the air, giving a luminous appearance in the dark.

Exp. If a stick be placed in a receiver of air, it will absorb the oxygen, and leave the nitrogen.

Exp. If a stick of phosphorus be dusted over with charcoal or resin, and placed under the receiver of an air pump, it will inflame on exhausting the air.

Exp. By friction it instantly ignites, and hence is employed for *matches.*

Exp. When ignited in oxygen, it burns with great brilliancy. This experiment should be conducted in a large globe-receiver, filled with oxygen, and the phosphorus placed in the centre by a pendant spoon. Dense white fumes of phosphoric acid are formed; these often mingle with the vapors of phosphorus and oxygen, which renders *the whole inflammable* and hence the danger of breaking the receiver.

Exp. Let a stream of oxygen gas upon it in a fused state, under water, and flashes of light will pass up through the water.

Exp. Or put a few grains of chlorate of potassa into a glass of water, in which is a piece of phosphorus, and from the dropping tube, pour on nitric or sulphuric acids—flashes of light will appear.

Exp. Drop a small piece into a glass containing a small quantity of strong nitric acid, it will burn vividly, and often *explode with great violence.*(See fig. 63.)

Exp. Sweet oil dissolves it by the aid of heat, and the phosphorized oil can be put on the face and hair, so as to render it luminous in the dark.

In all these cases, the light results from the union of phosphorus with oxygen; so strong is its affinity for oxygen that it should always be kept under water.

Relation to animals. It is very poisonous; acts as an excitant, and in large doses it proves fatal; but it is used sometimes as a medicine. It renders water poisonous in which it is kept.

Phosphorus and Oxygen.

Oxide of phosphorus. Symb. 3P+O. Equiv. 47.1+8=55.1. It is obtained by burning phosphorus under hot water, by a jet of oxygen gas. The substance which remains after combustion is of a red color, without taste or odor; insoluble in water, alcohol, ether, and oil; is not volatilized at 662° Far., but takes fire at a low red heat, in the air and in chlorine gas. This substance has been examined by M. Pelouse, and found to be an oxide of phosphorus.

Hypophosphorous acid—Symb. 2P+O. Equiv. 31.4+8=39.4—was discovered by Dulong in 1816, and is obtained by the action of water upon the phosphuret of barium. Hypophosphite of baryta is formed soluble in water; on filtering the solution and adding sulphuric acid to precipitate the baryta, the hypophosphorous acid remains, and is concentrated by evaporation into a viscid liquid, capable of crystallization; this is the *hydrate* of the acid, and is a *powerful deoxidizing agent.*

Phosphorous acid. Symb. 2P+3O. Eq. 31.4+24=55.4. Discovered by Davy, and may be obtained by subliming phosphorus through the *bichloride of mercury*, in a glass tube; a *limpid* liquid distils over, which is a compound of phosphorus and chlorine. Put this into water, and the hydrogen of the water unites with the chlorine, forming hydrochloric acid—and the oxygen of the water combines with the phosphorus, forming *the phosphorous acid.* The solution is then evaporated to the consistency of syrup, to expel the hydrochloric acid, and the phosphorus acid crystallizes as a *hydrate. The anhydrous* acid may be obtained by burning the phosphorus in highly rarefied air.

Properties. Sour to the taste, *odor* like garlick, and possesses acid properties; has a strong affinity for oxygen, and is hence easily converted into phosphoric acid; precipitates mercury, silver, platinum and gold, from their saline solutions, in the metallic form.

Phosphoric acid. Symb. 2P+5O. Eq. 31.4+40=71.4. Under the term of phosphoric acid, three compounds have formerly been described, affording a remarkable instance of a class of bodies, called *isomeric*, which are identical in composition, but possess different properties. The names given to the three compounds, are *phosphoric*, *pyrophosphoric*, and *meta* or *paraphosphoric acids.*

The phosphoric acid has hitherto been obtained only in combination with water or an alkaline base.

Process. The *superphosphate* of lime is boiled for a few minutes with excess of carbonate of ammonia, by which the lime is precipitated as a phosphate. After filtration the liquid is evaporated to dryness, and then ignited in a platinum crucible, to expel the ammonia and sulphuric acid.

Properties. Colorless, intensely sour, reddens vegetable infusions powerfully, and neutralizes alkalies. In the state of greatest concentration, it is composed of three equiv. of water, and one equiv. of acid, and may be made to crystallize in thin plates. It is remarkable for uniting with bases, in the proportion of one equiv. of the acid to three of the base, or the oxygen of the base, and the acid as three to five.

The pyro-phosphoric acid, is obtained by exposing concentrated phosphoric acid to a temperature of 145°.

Its properties are generally similar to the preceding, but is distinguished from it by yielding a snow-white precipitate, when neutralized with ammonia, and mixed with the nitrate of the oxide of silver. *It is remarkable for its tendency* to unite with two equiv. of a base to one of the acid.

Meta, or *paraphosphoric acid*, is obtained by burning phosphorus in dry air, or oxygen gas. The acid appears in small crystals like snow, on the interior of the vessel. It is formed, combined with water, by heating to redness the two preceding acids; when fused, it cools into a brittle and transparent solid, resembling ice, hence called *glacial phosphoric acid*, very deliquescent, and hence must be kept in close bottles.

It is distinguished from the others by uniting one equiv. of a base to one of the acid.

Phosphorus and Chlorine.

The sesqui-chloride of phosphorus—Symb. $2P+3Cl$. Equiv. $31.4+106.26=137.66$. Sp. gr. 1.45—may be formed by passing the vapor of phosphorus over corrosive sublimate, in a glass tube, or by heating the perchloride with the phosphorus.

Properties. It is a clear, limpid liquid, not acid by the chemical tests, though it emits acid fumes when exposed to the air. This is due to the affinity of the chlorine for the hydrogen of the water contained in the air. When mixed with water, mutual decomposition takes place with evolution of heat, and the formation of hydro-chloric, and phosphoric acids.

The perchloride of phosphorus is formed by the spontaneous combustion of phosphorus in chlorine gas. Symb. $2P+5Cl$. Eq. 208.5.

Properties. A white solid, volatile at a temperature below 212°; heated under pressure, it fuses, and forms, in cooling, transparent, prismatic crystals. Thrown into water, mutual decomposition ensues.

Iodides of Phosphorus. There appear to be three compounds of iodine and phosphorus, produced by the spontaneous combustion of the two substances.

The protiodide—Symb. $P+I$. Equiv. 142—has a yellow color, fuses at 212°, sublimes by heat unchanged, and is decomposed by water.

The sesquiodide—Symb. $2P+3I$. Equiv. 410.3—is a dark grey crystalline mass, fuses at 84°.

The periodide—Symb. $2P+5I$. Equiv. 662.9—is a black compound, fusible at 114°.

Bromides of phosphorus are formed by bringing phosphorus and bromine into contact, in a flask filled with carbonic acid.

The proto-bromide—Symb. $P+Br$. Equiv. 94.1—is a liquid formed at the bottom of the flask, easily converted into vapor by heat, acts energetically upon water, and mutual decomposition takes place.

The per-bromide—Symb. $2P+5Br$. Eq. 423.4—is a yellow solid, converted by heat into a red-colored liquid, and into a vapor of a similar tint. When cooled from fusion it yields rhombic crystals. Emits dense, penetrating fumes when exposed to the air, and is decomposed by water, and chlorine.

Phosphorus and Hydrogen.

Phosphuret of hydrogen—Symb. $2P+3H$. Equiv. $31.4+3=34.4$—called also *hyduret of phosphorus*, was discovered in 1812, by Sir H. Davy, by heating hydrated phosphorous acid in a retort.

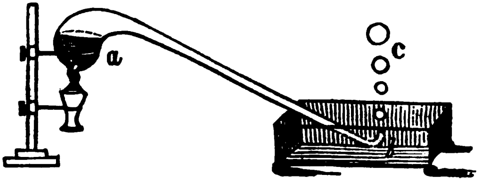
Properties. It is *colorless*, with the odor of garlick; does not take fire spontaneously in air, but instantly inflames in chlorine gas, with a white light; forms with oxygen a detonating mixture.

Per-phosphuret of hydrogen is isomeric with the preceding. It was discovered in 1783, by Gengembre, and since examined by Dalton, Thomson, and others. The names *phosphuretted hydrogen*, and *hyduret of phosphorus* have also been applied to it.

Preparation. For the purposes of experiment, it is easily prepared in the following manner: fill a pint retort half full of recently slacked lime, and put into it a stick of phosphorus two or three inches long, cut into strips. Then pour on a strong solution of carbonate of potassa, filling it quite full. Place the beak of the retort in the cistern and apply heat. The gas will soon form and inflame when it comes in contact with the air, forming beautiful wreaths of smoke which rise up from the water.

Properties. This gas is colorless, and has a highly offensive odor, and bitter taste, will neither support flame nor respiration.

Fig. 69.



Inflames spontaneously when admitted into air, and explosively with oxygen gas. As the bubbles of the gas (fig. 69.) rise through the water in the cistern *b* into the air, they *inflame* successively, forming a series of rings, as *c*, of dense white smoke, continually increasing in size as they arise, and producing one of the most striking and beautiful appearances in experimental chemistry. If a bubble of the gas is admitted into a receiver of oxygen gas, a bright flash of light is seen, and the receiver is jarred by the concussion. This is one of the most remarkable properties of this gas, and distinguishes it from all other gases. It is often produced by the decomposition of bones, in swamps and grave-yards, and gives rise to those lights which are frequently seen about such places. It is the real "Jack o' the lantern," or "Will o' the wisp."

Water absorbs one eighth vol. of this gas, and if suffered to remain over water for a few days, it loses its spontaneous inflammability, but will inflame on application of a lighted taper.

Phosphorus and Sulphur.

Sulphuret of phosphorus. The nature of this compound is not accurately settled; it is formed by bringing sulphur in contact with fused phosphorus. They act on each other with great violence, producing a compound of a reddish brown color; fuses at 16° Far., and is highly combustible.

SECT. 10. BORON.

Symb. B. Eq. 10.9. Equiv. vol. 100.

This substance was discovered in 1807 by Sir H. Davy, by exposing boracic acid to a powerful galvanic battery; but its properties were first investigated by Gay Lussac and Thenard, who obtained it in greater quantity by heating *boracic acid* with potassium.

The easiest method of obtaining it, is to decompose *borofluoride of potassium* by means of potassium and heat.

Properties. A dark *olive-colored solid,* without *taste* or *odor*, a *non-conductor* of electricity, sp. gr. nearly 2; insoluble in water, alcohol, ether and oils; does not decompose water at any temperature, and may be subjected to intense heat in close vessels without change; heated to 600° in the air it ignites, and is converted into boracic acid. When heated with nitric acid, or with any substance which yields oxygen freely, it passes into boracic acid.

Boron and Oxygen.

Boracic acid. Symb. $B+3O$. Equiv. 34.9. Sp. gr. 1.479, water 1. This substance exists in nature in small quantities in the Lipari Islands, and the hot springs of Lasso in the Florentine territory. In combination with soda, in the well known substance *borax, the biborate of soda*, used by smiths as a flux. It is also a constituent of the minerals *boracite* and *datholite.*

Process. To a *solution* of purified borax in boiling water, add half its weight of sulphuric acid, diluted with an equal quantity of water. On evaporation and cooling, shining crystals of boracic acid will be deposited; it may be purified by repeated solution in hot water and crystallization. This is a *hydrate*, containing 1 eq. of acid and 3 of water. The *anhydrous* acid may be obtained by heating this in a platinum crucible.

Properties. The *hydrous acid* exists in the form of *thin white scales*, without *odor* and nearly *tasteless*, sparingly soluble in water, which reddens vegetable blue colors, and like the alkalies turns tumeric paper brown, soluble in boiling alcohol, and gives a beautiful green color to flame.

The *anhydrous acid* is a hard, colorless, transparent glass, absorbs water rapidly from the air, and should be kept in well stopped vials; exceedingly fusible, and communicates this property to the substances with which it unites. Hence its use in the arts as a *flux.*

Boron and Chlorine.

Terchloride of Boron. Symb. $B+3Cl$. Eq. 117.16. Produced by the spontaneous combustion of boron in chlorine gas. It is rapidly absorbed by water, and unites with ammonia, forming a volatile fluid. It is also formed, according to Despretz, by passing dry chlorine gas over charcoal and boracic acid, ignited in a porcelain tube. It was first noticed by Davy, and examined by Berzelius, Dumas, and Despretz.

Boron and Fluorine.

Fluoboric acid. Symb. $B+3F$. Equiv. 66.94. Sp. gr. 2.3622. Discovered by Gay Lussac and Thenard in 1810.

Process. Mix 1 part of pure boracic acid and 2 of fluor-spar with 12 of sulphuric acid in a glass flask and apply heat, or heat a strong solution of hydrofluoric and boracic acids in a metallic retort.

Properties. A colorless gas of a penetrating *pungent odor*, extinguishes flame, reddens litmus powerfully, and unites with bases forming salts called *fluorborates.*

It has a powerful affinity for water, which absorbs 700 vols. of the gas, becomes hot, fuming and caustic, attacks animal and vegetable substances with great energy. Some doubt yet exists concerning its true nature.

Boron and Sulphur.

Sulphuret of boron is formed, according to Berzelius, by burning boron in the vapor of sulphur. The product is a white opaque mass, readily decomposed by water.

SECT. 11. SELENIUM.

Symb. Se. Equiv. 39.6. Sp. gr. 4.32.

Selenium was discovered by Berzelius in 1818, and named *Selenium,* from *Selene,* the moon, because he at first mistook it for tellurium.

Natural History. It is found in small quantities among the volcanic products of the Lipari Islands, in Clausthal in the Hartz, combined with lead, cobalt, silver, mercury and copper. Berzelius obtained it from the iron pyrites of Fahlun.

Process. Mix the native sulphuret of selenium with 8 times its weight of peroxide of manganese, and expose it to a low red heat in a glass retort, the beak of which dips into water. The manganese yields its oxygen to the sulphur, and the selenium sublimes pure, or in the form of selenious acid.

Properties. A brittle opaque solid, without taste or odor; its lustre is metallic, resembling lead in the mass, but the powder has a deep red color; softens at 212°, and may be drawn out into fine transparent threads, which appear red by transmitted light; becomes fluid a little above 212° and boils at 650°, yielding an inodorous vapor of a deep yellow color;

sublimes, in close vessels, without change, and condenses into dark globules, or into a cinibar red powder, if the vessels are large. Heated in the open air, or in oxygen, it combines with the oxygen; under the blow-pipe, it emits the strong odor of horse-radish.

Selenium and Oxygen.

Oxide of selenium—Symb. Se+O. Equiv. 47.6—is formed by heating selenium in a limited quantity of air, and washing the product to clear it from selenious acid. It is a colorless gas, which gives the peculiar odor to the selenium, when burned in the wick of a lamp.

Selenious acid—Symb. Se+2O. Equiv. 55.6—is formed by dissolving selenium in nitro-hydrochloric acid. On evaporation, the acid is left as a white, crystalline solid, of a sour and burning tase; dissolves readily in water and alcohol, and attracts moisture from the air. It has distinct acid properties, and its salts are called *selenites.* It is decomposed by all substances which have a strong attraction for oxygen.

Selenic acid—Symb. Se+3O. Equiv. 63.6—was first noticed by M. Nitzsch, and described by Mitscherlich in 1827.

Process. It is obtained by fusing nitrate of potassa or soda with selenium; a metallic seleniuret with selenious acid, or any of its salts. (For process see Turner, 6th ed. p. 209.)

Properties. A colorless liquid, sp. gr. at 329° 2.524, at 512° 2.60. It is decomposed by heat at 536°, and is resolved into oxygen and selenious acid; has a powerful affinity for water with which it combines, with the evolution of as much caloric as sulphuric acid and water. It dissolves zinc, iron, copper and gold; unites with bases and forms salts, analogous in composition and form, to those of sulphuric acid.

Chloride of selenium is a white solid, obtained by placing selenium in chlorine gas.

Bromide of selenium is an orange-colored solid; soluble in water, and obtained by dropping selenium into bromine. The combination is violent with the evolution of much heat.

Selenium and Hydrogen.

Hydro-selenic acid. Symb. $Se+H$. Eq. 41. This acid was discovered by Berzelius, and some doubt exists as to its composition.

Process. It may be obtained by the action of hydrochloric acid upon a concentrated solution of any *hydro-seleniate.*

Properties. A colorless gas, with an odor resembling hydrosulphuric acid. It irritates the membrane of the nose, exciting catarrhal symptoms, and produces temporary insensibility. Water absorbs it readily, and the solution reddens litmus, and leaves a brown stain upon the skin. On exposure to the air, it is decomposed, but decomposes all the salts of the common metals, forming *seleniurets* of the metal.

Selenium and Sulphur.

Bisulphuret of selenium—Symb. $Se+2S$. Eq. 71.8—was obtained by Berzelius, by adding hydrosulphuric acid to a solution of selenious acid, when it is precipitated as an orange-colored powder; fuses at 212°, sublimes at a high temperature without change; when heated in the open air, it inflames and is decomposed by nitro-hydrochloric acid.

Seleniuret of phosphorus, or *Phosphuret of selenium* is prepared in the same manner as the sulphuret of phosphorus. It is a very fusible substance; *inflammable*, and decomposes water slowly, yielding seleniuret of hydrogen, and one of the acids of phosphorus.

SECT. 12. SILICON.

Symbol Si. Equivalent 22.5

Silicon was obtained by Berzelius in 1824, by the action of potassium on fluocilicic acid gas. It was at first called *silicium*, and regarded as a metal, but it is destitute of the metallic properties.

Properties. Silicon is a solid, of a dark brown color, and a non-conductor of electricity.

Before ignition it is not oxidized, or dissolved by hot sulphuric or nitro-hydrochloric acids, but is soluble in hydrofluoric acid, and in a hot concentrated solution of caustic potassa. It burns readily in air, and vividly in oxygen gas; but after ignition, it is insoluble and non-combustible. It is oxidized by heating it with nitrate of potassa, and explodes when dropped upon fused hydrate of potassa, soda or baryta, in consequence of the evolution of hydrogen.

Silicon and Oxygen.

Silicic acid—silica. Symb. $Si+3O$. Eq. $22.5+24=46.5$.

Natural History. Silicic acid, also called *silica*, *silicous earth*, and *silex*, constitutes nearly 40 per cent. of the crust of the globe. Hence it is the principal ingredient of extensive mountain masses, of sand, and of several minerals, such as quartz, flint, calcedony, rock-crystal, etc.

Preparation. It may be prepared by heating rock-crystals, and throwing them red hot, into cold water.

Properties. When reduced to powder, it is white, insipid, and inodorous. It is very infusible, requiring the heat of the compound blow-pipe to fuse it; insoluble in water, unless presented in the nascent state; does not act upon test paper, but in every other respect, has the properties of an acid. Its combination with the fixed alkalies, is effected by mixing pure sand with carbonate of potassa. If three parts of the carbonate to one of sand are mingled, the fused *silicate* is soluble in water; but if one part of the carbonate to three of sand be employed and fused, the well known substance *glass* is formed, which is transparent, brittle, insoluble in water, and affected by no acid except the hydrofluoric.

Every kind of common glass is a *silicate*, and the different varieties are due to the proportions of the constituents, to the nature of the alkali, or the presence of foreign matter. Thus *green bottle glass* is made of materials containing iron. *Crown-glass* of pure alkali and sand, free from iron. *Plate glass* for mirrors is made of the purest materials. *Flint glass* contains red lead, and sometimes peroxide of manganese, or nitre is added to oxidize the carbon contained in the materials.

Chloride of silicon—Symb. $Si+Cl$. Equiv. 57.92—is prepared by burning silicon in chlorine gas. The product is a limpid, volatile liquid, flying off in white vapor when exposed to the air, with a suffocating odor resembling cyanogen, boils at 124° Far.

Bromide of Silicon—Symb. Si+Br. Equiv. 100.6—was obtained by Serullas, in the same manner as the chloride. It is a very dense, colorless liquid, emitting dense fumes.

Sulphuret of silicon—Symb. Si+S. Equiv. 38.6—is formed by heating silicon in the vapor of sulphur. It is a white, earthy substance, instantly converted by the action of water into hydrosulphuric and silicic acids.

Fluo-silicic acid—Symb. Si+F. Equiv. 41.18—is formed, by bringing hydrofluoric, and silicic acids into contact. It is a colorless gas, which extinguishes flame, destroys animals immersed in it, and acts powerfully upon the respiratory organs. Water acts upon this gas with some change of properties, and the solution is called *silico-hydrofluoric acid.*

CHAPTER II.

CLASS II. METALS WITH THEIR PRIMARY COMPOUNDS.

General properties of Metals.

Metals are the most important of substances. They are distinguished from other substances by the following properties:

1. They are all conductors of electricity and of caloric.

2. When combined with oxygen, chlorine, iodine, sulphur, and similar substances, and subjected to the voltaic battery, they always go to the negative electrode or pole, and hence are called positive electrics.

3. Metals are opaque, that is, they do not permit the light to pass through them, although reduced to thin leaves.

4. They are good reflectors of light, and possess a peculiar lustre, which is termed the *metallic lustre.* Any substance, which has the above properties, may be regarded as a metal.

Metals differ greatly in their properties.

1. *In their specific gravity.* Most of the metals are remarkable for their weight, such as gold and platinum, which are more than nineteen times as heavy as an equal bulk of

water; while some, potassium and sodium, are lighter than water.

2. *In their malleability*, or the property of being beaten into thin leaves by hammering. Gold, silver, copper, tin, platinum, palladium, cadmium, lead, zinc, iron, nickel, potassium, sodium, and frozen mercury are malleable. The others are malleable only in a slight degree, or like arsenic, antimony and bismuth, brittle. Gold is the most malleable of metals; one grain of which may be extended so as to cover fifty-two square inches of surface, and to have a thickness not exceeding $\frac{1}{282020}$ of an inch.

3. *In their ductility*, or the property of being drawn out into wires. Most of the malleable metals are also ductile. Gold, silver, platinum, iron, and copper are the most *ductile*. Gold wire may be obtained so fine that it shall not exceed $\frac{1}{5000}$ of an inch in diameter, and platinum $\frac{1}{30000}$ of an inch. The *tenacity* of a metal is measured by the weight which a wire of a certain diameter can support without parting.

4. *In hardness*. Titanium, manganese, iron, nickel, copper, zinc, and palladium are hard metals. Gold, silver, and platinum are softer than these, lead still softer, and potassium and sodium yield readily to the pressure of the fingers.

5. *In their structure*. Many have a crystalline structure. Iron is fibrous; zinc, bismuth, and antimony are lamellated; gold, silver, and copper are found naturally in crystals, and others may be made to assume the form of crystals, when they pass gradually from a liquid to a solid state. Most of them in crystallizing assume the figure of a cube, the regular octohedron, or some form allied to it.

6. *In their fusibility*. All are solid, at the common temperature of the atmosphere, except mercury, which is solid at −40° Far. Mercury, potassium, sodium, cadmium, tin, bismuth, lead, tellurium, antimony, and probably arsenic are fusible below read heat. The rest require a higher temperature to fuse them, and some of these, such as platinum, ceri-

um, rhodium, and columbium require the heat of the compound blow-pipe to render them liquid.

7. *In volatility.* Cadmium, mercury, arsenic, tellurium, potassium, sodium, and zinc are volatilized by heat. Most of the others may be exposed to the most intense heat of a smith's forge, without being converted into vapor.

8. *In their affinity for the other simple substances.* Metals generally have an extensive range of affinity; hence they are rarely found in the earth in their simple or *native* state, but are generally combined with other bodies, especially with oxygen and sulphur, in which state they are said to be *mineralized.*

It is a remarkable fact, that they are not disposed to combine with compound bodies. They combine with each other and with other simple substances, generally in a few *definite proportions.*

They all combine with oxygen, though with different degrees of energy. Iron and copper are slowly oxidized at common temperatures, while gold will sustain the most intense heat of furnaces without oxidation. Potassium and sodium will even decompose water, to obtain the oxygen, the moment they come in contact with it. In all these cases they produce the phenomena of combustion. Hence they are said to be *combustible.* With chlorine, iodine, bromine, etc., they combine with more or less energy, giving rise to the same phenomena. Some unite with oxygen in one proportion only, but most have two or three degrees of oxidation.

Metallic oxides may be reduced to the metallic state by heat, by the united agency of heat and combustible matter, by voltaic electricity, and by the action of the deoxidizing agents on metallic solutions.

Many metals form acids with oxygen, as well as oxides; but one only, arsenic, is capable of forming an acid, and not an oxide.

Many of the metallic oxides combine with acids and form salts, and generally the protoxide is the *only salifiable base.*

Oxides sometimes combine with each other and form definite compounds, The action of the metals upon the simple non-metallic substances, will be noticed in their proper place. —The number of metals is forty-two, and the following table contains their names, with the date at which they were discovered, and the names of the chemists by whom the discovery was made.

Names of Metals.	Authors of the Discovery.	Dates of the Discovery.
Gold	Known to the Ancients.	
Silver		
Iron		
Copper		
Mercury		
Lead		
Tin		
Antimony	Described by Basil Valentine	1490
Bismuth	Described by Agricola	1530
Zinc	First mentioned by Paracelsus	16th century.
Arsenic	Brandt	1733
Cobalt		
Platinum	Wood, assay-master, Jamaica	1741
Nickel	Cronstedt	1751
Manganese	Gahn and Scheele	1774
Tungsten	D'Elhuyart	1781
Tellurium	Müller	1782
Molybdenum	Hielm	1782
Uranium	Klaproth	1789
Titanium	Gregor	1791
Chromium	Vauquelin	1797
Columbium	Hatchett	1802
Palladium	Wollaston	1803
Rhodium		
Iridium	Descotils and Smithson Tennant	1803
Osmium	Smithson Tennant	1803
Cerium	Hisinger and Berzelius	1804
Potassium	Davy	1807
Sodium		
Barium		
Strontium		
Calcium		
Cadmium	Stromeyer	1818
Lithium	Arfwedson	1818
Zirconium	Berzelius	1824
Aluminium	Wöhler	1828
Glucinium		
Yttrium		
Thorium	Berzelius	1829
Magnesium	Bussy	1829
Vanadium	Sefström	1830
Latanium	Mosander	1839

It will be found convenient in studying the properties of the metals to arrange them in groups. They may be divided for this purpose into the two following classes.

Class I. Metals which by oxidation yield alkalies or earths.

Class II. Metals, the oxides of which are neither alkalies nor earths.

The first class includes twelve metals, which may be arranged in three orders.

Order 1. Metallic bases of the alkalies. These are,

Potassium,
Sodium,
Lithium.

Order 2. Metallic bases of the alkaline earths. These are,

Barium,
Strontium,
Calcium,
Magnesium.

Order 3. Metallic bases of the earths. These are,

Aluminium,
Glucinium,
Yttrium,
Thorium,
Zirconium.

Class II. The metals belonging to this class are arranged in the three following orders:

Order 1. Metals which decompose water at a red heat:

Manganese,
Iron,
Zinc,
Cadmium,
Tin,
Cobalt,
Nickel.

Order 2. Metals which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by the sole action of heat:

Arsenic,
Chromium,
Vanadium,
Molybdenum,
Tungsten,
Columbium,
Antimony,
Uranium,
Cerium,
Bismuth,
Titanium,
Tellurium,
Copper,
Lead.

Order 3. Metals, the oxides of which are decomposed by a red heat:

Mercury,
Silver,
Gold,
Platinum,
Palladium,
Rhodium,
Osmium,
Iridium.

T.

Sect. 1. Metallic bases of the Alkalies.

POTASSIUM. Symb. K. Equiv. 39.15. Sp. gr. 0.865.

History. The discovery of *potassium*, or *Kalium* as it was at first called, was made by Davy in 1807, and constitutes an era in the history of chemical philosophy, as it led to the discovery of the metallic bases of the other alkalies and alkaline earths, and to the decomposition of a variety of compounds which were before regarded as simple bodies.

The discovery was made by subjecting the *hydrate* of potassa, to the influence of a powerful galvanic battery of 200 pair of plates; oxygen appeared at the positive, and a small globule of a metallic lustre at the negative pole, which proved to be the metal *potassium.*

Process. Potassium is obtained in small quantities by galvanism; but the best method is that of M. Curaudau, which was improved by Brunner, and modified by Wohler. The substance employed is carbonate of potassa, prepared by heating cream of tartar to redness in a covered crucible. This is raised to a high temperature, in connection with charcoal, in an iron retort; the oxygen of the potassa combines with the carbon, and the potassium distils over.

Properties. Potassium, at common temperatures, is a soft malleable solid, yielding to the pressure of the fingers, like wax; of a decidedly metallic lustre, similar to mercury in color; somewhat fluid at 70°, and perfectly liquid at 150°; cooled to 32°, it is *brittle;* sublimes at a low red heat in close vessels secluded from the air; a good conductor of electricity and of caloric.

But its most remarkable property is its affinity for oxygen. It oxidizes rapidly in the air or oxygen gas, but if a piece be thrown upon water, it will decompose it rapidly, disengaging so much heat that the potassium takes fire, and burns with a beautiful *purple flame.* The evolution of hydrogen gas causes it to move about upon the surface of the water, and combining with the potassium, augments the brilliancy of the combustion.

Exp. Invert a wine-glass filled with water in the cistern, and introduce a small piece of potassium, it will rapidly decompose the water, and the escape of hydrogen gas will displace the water in the glass. This gas may then be ignited.

Exp. Heat a small piece of iron and drop upon it potassium; then invert over it a jar of oxygen gas.

Exp. Drop a piece upon ice, and it will instantly inflame; a deep hole is made in the ice, containing pure potassa.

Exp. To show that the action of potassium upon water produces an alkali, drop a small piece into a bottle containing vegetable infusion, and it will instantly *turn it green.* In consequence of its affinity for oxygen, it must be kept under naptha, or the essential oil of copaiba.

Remark. In the description of the metallic compounds, the abbreviations *symb.* and *equiv.* will be omitted, and the symbols and equivalents placed immediately after the names of the substances.

Compounds of Potassium.

Protoxide of potassium, K+O. 47.15, commonly called *potash,* or *potassa,* is always formed when potassium is put into water, or burned in oxygen gas. It exists in nature in the minerals, feldspar, mica, and several others—in all vegetables, from which it is obtained by leaching their ashes, and boiling the lye.

Properties. The pure potassa is a white solid, very caustic, possessing *powerful alkaline properties;* easily fused by heat, but not decomposed; deliquesces in the air, and hence is very soluble in water, forming with it a *hydrate,* which retains the water under the *most intense heat.*

The hydrate of potassa contains 1 eq. of water, and is similar in its properties to the *anhydrous* potassa. The aqueous solution of the hydrate, called *aqua potassae,* may be prepared by decomposing the carbonate with lime.

Exp. Put quick lime with ½ its weight of carbonate of potassa, dissolved in 8 or 10 times its weight of water, into a clean iron vessel, and put it into well stopped bottles to exclude the air, from which it will absorb carbonic acid; if the solution is pure, it will not effervesce with acids. The *solid hydrate* may be made from this by evaporation, and further purification by alcohol, which dissolves only the pure hydrate;

the alcohol is then driven off by heat. This was formerly called *lapis causticus*, but the colleges of Edinburgh and London called it *potassa fusa.*

Tests. Potassa may be distinguished from all other substances by the precipitates thrown down from its salts in solution.

Exp. 1. Tartaric acid gives a white precipitate, the bitartrate of potassa.

Exp. 2. Chloride of platinum, a *yellow*, and when dissolved in alcohol, a *pale yellow* precipitate.

Exp. 3. Alcoholic solution of carbazotic acid, throws down yellow crystals of carbazotate of potassa. This is the most delicate test.

Uses. Potassa, being a very powerful alkali, is of great use in chemistry and the arts. It forms the bases of most soaps; the *crude potash* is employed for making glass. — Owing to its affinity for carbonic acid, it is used for abstracting that substance from gaseous mixtures, and for depriving them of moisture.

Teroxide of Potassium, $K+3O$. 63.15, is formed when potassium is burned in the air or oxygen gas. It is an orange-colored substance, *caustic*, alkaline, heavier than potassium, and decomposed by galvanism and by water—by the latter it is resolved into the protoxide and oxygen; fuses below a red heat, in which state it burns vividly, in contact with combustibles.

Chloride of Potassium, $K+Cl$. 74.57, was long known by the names '*febrifuge salt of Sylvius*,' '*regenerated sea-salt.*'

It may be formed by the spontaneous combustion of potassium in chlorine, or by dissolving potassium in hydrochloric acid, and evaporating the solution slowly to dryness.

Properties. It occurs in *cubic crystals*, colorless, of a *saline* and *bitter taste*, insoluble in alcohol, and soluble in 3 parts of water at 60°, and in less at 212°.

Iodide of Potassium, $K+I$. 165.45, is formed by heating potassium with iodine, or by heating the iodate of potassa.

Properties. Fuses readily, and is converted into vapor below a red heat; deliquesces in air; very soluble in water; dissolves in strong alcohol, and by evaporating the solution, yields *colorless cubic crystals* of iodide of potassium.

Bromide of Potassium, $K+Br$. 117.55, formed by a process similar to that for the iodide (using bromine instead of iodine), and has similar properties; very *soluble* in water, which by evaporation yields anhydrous cubic crystals; easily fused and decrepitates like sea-salt, when heated.

Exp. Put a small piece of potassium into a wine-glass containing a few drops of bromine, they will combine with explosive violence.

Fluoride of potassium, $K+F$. 57.83, is formed by merely saturating hydrofluoric acid with carbonate of potassa, evaporating to dryness, and igniting to expel excess of acid.

Properties. It has a sharp saline taste, alkaline to the test papers, soluble in water, and the solution acts on glass. It is obtained from its solution, by evaporation at 100°, in cubes or rectangular *four-sided prisms, very deliquescent.*

Hyduret of potassium. Discovered by Gay Lussac and Thenard, and may be formed by heating potassium in hydrogen gas. It is a grey solid, readily decomposed by heat or water. Gaseous hyduret of potassium is produced when hydrate of potassa is decomposed by iron, at a white heat. It is a colorless gas, and burns spontaneously in air or oxygen gas, but loses its inflammability by standing over mercury.

Nituret of potassium consists, according to Thenard, of 100 parts of potassium to 11.728 of nitrogen, and formed by heating potassium with ammoniacal gas.

Sulphurets of potassium. These are five in number, dependent on the quantity of sulphur.

The proto-sulphuret of potassium, $+KS$. 55.25, is prepared by burning potassium and sulphur in the air, or by decomposing the sulphate of potassa by charcoal or hydrogen gas at a red heat. Mixed with powdered charcoal, it *kindles spontaneously*.

The bisulphuret of potassium, $K+2S$. 71.35, is formed by exposing a saturated, alcoholic solution of hydrosulphate of sulphuret of potassium, until a pellicle begins to form, and then evaporating to dryness.

The tersulphuret of potassium, $K+S$. 87.45, is formed by heating carbonate of potassa to low redness, with half its weight of sulphur, known by the name of *liver of sulphur*.

The quadro-sulphuret of potassium, $K+4S$. 103.55, is prepared by transmitting the vapor of *bisulphuret of carbon* over sulphate of potassa at a red heat, until carbonic acid gas ceases to be disengaged.

The quinto-sulphuret of potassium, $K+5S$. 119.65, is formed by fusing carbonate of potassa, with its own weight of sulphur.

The properties of the four last compounds are similar; they are deliquescent, have a sulphureous odor, and are soluble in water. A solution of the last dissolves sulphur, and renders it probable that other compounds may be formed.

Phosphurets of potassium. Several compounds exist, but their composition is unknown. Obtained by burning potassium in phosphuretted hydrogen.

Seleniuret of potassium. Formed by fusing potassium and selenium together. They combine with explosive violence, and a crystalline, fusible compound results, of an iron grey color, and metallic lustre.

Cyanuret of potassium, $K+Cy$. 65.54, is formed by heating to redness the *anhydrous ferro-cyanuret of potassium* in an iron bottle.

Properties. Easily fused, and crystallizes in colorless cubes, pungent and alkaline to the taste, and poisonous, acting like hydro-cyanic acid; deliquescent, and very soluble in water; used sometimes as a medicine.

Sulpho-cyanuret of Potassium. $K+Cy$. 97.74.

SODIUM. Symb. Na. Equiv. 23.3. Sp. gr. 0.972.

Sodium was discovered by Sir H. Davy in 1817, a few days after the discovery of *potassium*, and by a similar process.

Process. It may be obtained in small quantities by galvanism. But the process of obtaining it from soda, now generally practised, is precisely the same as that for potassium.

Properties. Sodium resembles potassium in many of its properties. It is a white, opaque solid, of a metallic lustre, resembling silver; yields readily to the pressure of the fingers, and may be formed readily into leaves; fuses at 200° Far. and is vaporized at a red heat.

Sodium has so strong an affinity for oxygen, that it rapidly decomposes water to obtain it, but does not inflame unless the water is heated, in which case it throws out beautiful scintillations, often with *violent combustion.*

Exp. Thrown upon water, it moves about upon its surface, having the appearance of a silver ball, gradually growing less till the whole disappears.

It oxidizes in the air or oxygen gas, but not so rapidly as potassium; hence, like that metal, it must be kept under naptha. The product of its combustion in oxygen and its action upon water, is *soda*, the alkaline properties of which may be tested by dropping a small piece of the metal into a bottle containing a vegetable infusion.

Compounds of Sodium.

Protoxide of sodium, NaO. 31.3, commonly called ***soda***, and by the Germans *Natron*, is formed by the oxidation of sodium in air, or water.

Properties. A grey solid, similar to potassa, which it resembles in most of its properties; very caustic, and has powerful alkaline properties.

The hydrate has 1 eq. of water, and is easily fused. In other respects, it is similar to the *anhydrous* soda; absorbs carbonic acid from the air, and passes into carbonate.

It is distinguished from other alkaline bases by yielding, with sulphuric acid, the well known substance, called *Glauber's salts.* All its salts are soluble in water, and are not precipitated by any re-agent, and give a rich color to the blowpipe flame. The soda of commerce is generally a carbonate prepared from the ashes of marine plants, in the same manner as potash is from land plants.

Uses. Employed for the manufacture of hard soaps, and for culinary and medical purposes.

Sesqui-oxide of sodium, $2Na+3O$. 70.6, is formed when sodium is heated to redness, in excess of oxygen gas. It has an *orange-color*, but no *acid* or *alkaline* properties. It is resolved by water into soda and oxygen.

Chloride of sodium. $Na+Cl$. 58.72. This substance is formed by burning sodium in chlorine gas, or by saturating soda with hydrochloric acid, and evaporating to dryness. It is a very abundant natural product, under the name of *rock-salt.* It exists in sea-water, and salt-springs, from which it is obtained by evaporation. Great quantities are manufactured on the sea-coast of New-England, and at Salina, N. Y. The water at the latter place, according to the analysis of Beck, contains ⅐ of its weight of pure dry chloride of sodium.

Properties. A well known solid, crystallizing in *regular cubes*, and by sudden evaporation, in *hollow, quadrangular pyramids.* It is dissolved in 2½ times its weight of water, at

60° Far.; gradually fuses when heated, and decrepitates when thrown into the fire; is decomposed by carbonate of potassa and nitric acid.

Uses. The utility of salt, depends on its property of preserving animal and vegetable substances from putrescence. It is a remarkable fact, that dry salt is a *chloride of sodium*, a solution of salt is a *hydrochlorate of soda.*

Iodide of sodium. $Na+I$. 149.6. Prepared in the same manner as the iodide of potassium; exists in sea-water, salt-springs, and in the residual liquor from kelp.

Bromide of sodium. $Na+Br$. 101.7. Analogous to sea-salt, exists in sea-water and salt-springs, and crystallizes in cubes.

Fluoride of sodium, $Na+F$. 41.93 is formed by neutralizing hydrofluoric acid with soda; crystallizes in cubes, and when carbonate of soda is present, in octohedrons. Nearly insoluble in alcohol, soluble in 25 times its weight of water, attacks glass vessels when evaporated in them, *a property which is common to most of the compounds of fluorine.*

Sulphuret of sodium, $Na+S$. 39.4 is obtained in the same manner as the proto-sulphuret of potassa, and has similar properties.

The cyanuret of sodium, $Na+Cy$, 49.69, and the *sulpho-cyanuret of sodium,* $Na+CyS^2$. 81.89, are similar to the corresponding compounds of potassium.

Chloride of soda is prepared by passing a current of chlorine gas into a cold solution of caustic soda. This liquor has received the name of *Labarraque's disinfecting soda liquid,* and is used extensively in the arts, and in medicine.

Properties. A liquid of a pale yellow color, with slight odor of chlorine. Its taste is sharp, saline, and but little alkaline; reddens tumeric, and then bleaches it. When evaporated it yields damp crystals; decomposed by exposure to the air.

Uses. It may be used for all the purposes of bleaching to which chlorine was formerly applied, in medicine to purify apartments, dissecting rooms, for destroying the fetor of ulcers, and for removing the offensive odors of sewers, drains, and all kinds of animal putrescence.

Alloy of sodium and potassium—10 parts of potassium, and 1 of sodium, from an alloy which is liquid at zero Far., and is lighter than naptha, or rectified petroleum.

LITHIUM. Symb. L. Equiv. 6.44.

This substance was obtained by Davy, by means of galvanism, as a *white-colored metal* like sodium, but it oxidized so rapidly that he was unable to examine its properties.

Compounds of Lithium.

Protoxide of lithium, lithia, L+O. 14.44, was discovered in 1818 by M. Arfwedson, in the mineral petalite; it exists in *spodumene*, *lepidolate*, and several varieties of mica.

Preparation. One part of petalite to two of fluor-spar, are finely pulverized, and the mixture heated with four times its weight of sulphuric acid till the acid vapors are disengaged. Sulphate of lithia and alumina are formed. These salts are then dissolved in water, and boiled with pure ammonia to precipitate the alumina; filter and evaporate to dryness, and then expel the sulphate of ammonia by a red heat. The result is a pure sulphate of lithia, which must be decomposed by acetate of baryta, and the acetate, by a red heat, is converted into the carbonate, and this reduced to the *caustic hydrate*, by boiling it with lime.

Properties. Similar to potassa and soda, in its alkalinity, and chemical relations. It is distinguished from them by its greater *neutralizing power*; when exposed to the air it absorbs carbonic acid, and becomes opaque.

Chloride of lithium, L+Cl. 41.86, is obtained by dissolving lithia in hydrochloric acid, evaporating to dryness, and fusing the residue.

Properties. A white, semi-transparent solid, and like the chlorides of potassium and sodium, forms by evaporation colorless, anhydrous, cubic crystals, which differ from those chlorides in being very deliquescent, dissolving freely in water and alcohol, and tinging the flame of alcohol red.

Fluoride of lithium, L+F. 25 12, prepared by dissolving lithia in hydrofluoric acid, and is a very fusible solid.

SECT. 2. METALLIC BASES OF THE ALKALINE EARTHS.

BARIUM. Symb. Ba. Equiv. 68.7.

Barium was discovered by Davy in 1808.

Process. The process consisted in forming the carbonate of baryta into a paste with water, placing a globule of mercury in a small hollow made in its surface, and laying the paste on a platinum tray, which communicated with the positive pole of a galvanic battery of 100 double plates, while the negative wire was in contact with the mercury. The baryta was decomposed, and its barium entered into combination with the mercury. This amalgum was heated in a vessel, free from air, by which means the mercury was expelled, and the barium obtained in a pure state.—T.

Properties. The metal, thus obtained, has a dark grey color, with a lustre inferior to cast iron. It is much heavier than water; it even sinks in sulphuric acid. Its attraction for oxygen is scarcely less than that of the preceding metals; is converted into baryta by exposure to the air; decomposes water with effervescence, from the escape of hydrogen gas. It has been obtained but in small quantities, and its properties are not accurately defined.

Compounds of Barium.

Protoxide of barium, or *baryta*, Ba+O. 76.7, was discovered by Scheele in 1774, and called *barytes* or *baryta*, from the great density of its compounds.

Process. It is the sole product of the oxidation of barium in the air, and in water. It is also obtained by exposing the nitrate of baryta to a red heat, or the carbonate, mixed with charcoal, to an intense white heat.

Properties. Baryta is a grey powder, sp. gr. 4., very difficult of fusion; has a sharp, caustic, alkaline taste, with other alkaline properties; insoluble in alcohol, but has a strong affinity for water, and slacks like lime, but with the evolution of more intense heat, and is converted into a white, bulky *hydrate*, which fuses at a red heat, but cannot be deprived of its water at the highest temperature of a smith's forge. A saturated solution yields on evaporation transparent, flattened, prismatic crystals, containing 10 atoms of water to 1 of baryta.

This solution is an excellent test of carbonic acid, or other gaseous mixtures in the atmosphere. The acid gives a milky appearance to the clear solution, due to the solid carbonate of baryta which is precipitated.

Distinguished by all its soluble salts, being precipitated by alkaline carbonates, and by the insoluble sulphate which cannot be separated by any other acid.

Binoxide of barium, Ba+2O. 84.7, is formed by conducting dry oxygen gas over pure baryta, at a red heat. It is a greyish-white substance, employed by Thenard in obtaining the binoxide of hydrogen.

Chloride of barium, Ba+Cl. 104.12, is prepared by decomposing a solution of sulphuret of barium with hydrochloric acid, or by conducting chlorine gas over baryta, at a red heat. On concentrating the solution, the chloride crystallizes in flat, four-sided tables, bevelled at the edges like crystals of heavy-spar. They consist of 1 equiv. of the chloride, to 2 of water.

Properties. Pungent and acrid to the taste. The crystals do not change in moist air; but in a very dry air, at 60° they lose their water of crytallization, and are rendered anhydrous at a full red heat—decomposed by sulphuric acid and alkaline carbonates.

Iodide of barium, Ba+I. 195., is formed by acting on baryta with hydriodic acid, and evaporating the solution. Soluble in water, and forms colorless, needle-shaped crystals.

Bromide of barium, Ba+Br. 147.1, is prepared by boiling proto-bromide of iron with moist carbonate of baryta, evaporating the filtered solution, and heating the residue to redness. The product crystallizes by careful evaporation, in white rhombic prisms, which have a bitter taste; are slightly deliquescent, and soluble in water, and alcohol.—T.

Fluoride of barium, Ba+F. 87.38, is prepared by digesting moist carbonate of baryta in hydrofluoric acid. It is a white powder, soluble in nitric and hydrochloric acids.

Sulphuret of barium, Ba+S. 84.8, is prepared by passing dry hydrosulphuric acid over pure baryta, at a red heat. It dissolves readily in hot water, and deposits colorless crystals on cooling. It may be employed for obtaining pure baryta by a process described by Turner, 5th ed. p. 308.

Cyanuret of barium, Ba+Cy. 95.09, is procured by the action of hydrocyanic acid on baryta. It is slightly soluble in water, has an alkaline reaction, and is decomposed by the carbonic acid of the air.

Sulpho-cyanuret of barium, Ba+CyS^2. 127.29, is obtained in the same way as the sulpho-cyanuret of potassium. It is very soluble in water, and crystallizes in beautiful needles, slightly deliquescent.

Phosphuret of barium, is formed by heating to redness anhydrous caustic baryta, and throwing into it pieces of phosphorus. It decomposes water, and forms phosphuret of hydrogen.

STRONTIUM. Symb. Sr. Equiv. 43.8.

Strontium was discovered by a process similar to that for *barium*, which it resembles in most of its properties; oxidizes in the air; decomposes water, by which process it is converted into *strontia*.

Compounds of Strontium.

Protoxide of strontium, Sr+O. 51.8, was discovered by Dr. Hope in 1792; also by Klaproth.

Preparation. It was formerly extracted from *strontianite* (a carbonate of strontia), found at Strontian in Scotland, hence its name. It may be prepared from the nitrate, or carbonate of strontia, in the same manner as baryta.

Properties. It resembles baryta in most of its properties. A grey substance, pungent and acrid to the taste; slaked with water it produces intense heat, and is converted into a *hydrate* which fuses readily, but the highest temperature of a blast furnace will not separate the water; soluble in boiling water, and crystallizes on cooling. The solution, like baryta, is an excellent *test* of carbonic acid.

Peroxide of strontium, Sr+2O. 59.8, is prepared in the same way as the peroxide of barium, and like it is employed to form binoxide of hydrogen; decomposed by dilute acids into strontia and oxygen. It is white, of a brilliant lustre, inodorous, and nearly tasteless.

Chloride of strontium, Sr+Cl. 79.22, is obtained in a manner precisely similar to the chloride of barium; crystallizes from its solutions in colorless prismatic crystals, which are distinguished from baryta by being soluble in twice their weight of water at 60°, and by the red tinge which it gives to the flame of an alcoholic solution. The anhydrous chloride fuses at a red heat, and yields a white, crystalline, brittle mass on cooling.—T.

Iodide of strontium. Sr+I. 170 1. is prepared in the same manner as iodide of barium. It is very soluble in water, fuses without decomposition in close vessels, but is resolved into iodine and strontia, by a red heat, in the open air.

Fluoride of strontium, Sr+F. 62.48, is obtained in the same way as the fluoride of barium. It is a white powder, sparingly soluble.

Proto-sulphuret of strontium, Sr+S. 59.9, is similar in its properties, and modes of preparation, to the corresponding compound of barium.

CALCIUM. Symb. Ca. Equiv. 20.5.

Calcium was discovered by Davy in 1808, by exposing lime to the action of the galvanic battery.

Properties. It is of a whiter color than barium, and is converted into lime by oxidation. Its other properties are unknown.

Compounds of Calcium.

Protoxide of calcium, Ca+O. 28.5, is generally obtained by burning common limestone (carbonate of lime) in kilns, for three or four days, to expel the carbonic acid. It is then called *lime*, or *quick lime*. The purest lime is prepared from the Iceland spar, or Carrara marble.

Properties. A brittle, greyish-white, earthy solid, of an acrid, caustic and alkaline taste, sp. gr., 2.3, difficult of fusion, but promotes the fusion of other bodies, and is hence used as a flux in smelting the ores of the metals. It has a strong affinity for water, with which it combines with the disengagement of heat, and forms the hydrate—a bulky, white substance, called *slaked lime*. This parts with its water at a red heat, and is more soluble in cold than in hot water.

Lime water. This is simply a solution of the hydrate, and possesses similar properties, absorbs carbonic acid from the air, and should therefore be kept in close vessels. It is a most delicate test of carbonic acid, a property already noticed under carbon.

Uses. The uses of lime are well known for a cement, for plaster, and as an anti-acid in medicine. A substance almost indispensable in every civilized country, and hence the Creator has made it very abundant and widely diffused, (the carbonate forming $\frac{1}{7}$ part of the crust of the globe).

Peroxide of calcium, $Ca+2O$. 36.5, is similar in properties, and in the mode of preparation, to the peroxide of barium.

Chloride of calcium, $Ca+Cl$. 55.92, exists in sea-water and some saline springs, and may be formed by dissolving marble in hydrochloric acid. On evaporation, the solution yields colorless prismatic crystals, which consist of 10 eq. of water to 1 of the chloride; these are rendered anhydrous by heat, and fuse at a red heat, but absorb the water again from the air, and deliquesce, owing to their strong attraction for water. It is much used for *freezing mixtures* with snow. Soluble in alcohol, with which it forms a definite compound.

Iodide of calcium, $Ca+I$. 146.8, is prepared by digesting hydrate of lime with protoxide of iron. It is a white, fusible compound, deliquescent, and very soluble in water; the solution will dissolve a large quantity of iodine, and on evaporation, yield the *periodide of calcium*, in black, prismatic crystals.

Bromide of calcium, $Ca+Br$. 98.9, is prepared in the same manner as the iodide, which it resembles in its properties.

Fluoride of calcium. $Ca+F$. 39.18. This is an abundant natural product, generally called *fluor-spar* or *Derbyshire spar*. It occurs in beautiful cubic crystals, the primary form of which, is an octohedron, used extensively for ornamental purposes, and is justly celebrated for the variety and beauty of its colors; fuses at a red heat, insoluble in water, and is decomposed by sulphuric acid; thrown in coarse powder on hot iron, it emits beautiful phosphorescent light, varying from red to purple and green.

Proto-sulphuret of calcium, $Ca+S$. 36.6, may be prepared by exposing sulphate of lime to a strong heat in a charcoal crucible. It is white with a reddish tint, and possesses the remarkable property of becoming phosphorescent by exposure to the light. It is the essential ingredient in *Canton's phosphorus*.

Bisulphuret of calcium, $Ca+2S$. 52.7, occurs in orange-colored crystals, prepared by boiling 3 parts of slaked lime, 1 of sulphur, and

20 of water for a few hours, and setting the solution aside in bottles corked tight for several days. When either of the above solutions is boiled with sulphur, the solution contains calcium with 5 equiv. of sulphur—the *quinto-sulphuret of calcium*, $Ca+5S$. 101.

Phosphuret of calcium, $Ca+P$. 36.2, is formed by passing the vapor of phosphorus over quick lime, at a low red heat. It is a brown substance, and when thrown into water, forms by mutual decomposition, *phosphuretted hydrogen*, *hypo-phosphorous acid*, and *phosphoric acid*.

Chloride of lime. $Ca+O+Cl$. 63,92. This substance, commonly called *oxymuriate of lime*, or *bleaching powder*, is prepared by exposing recently slaked lime to an atmosphere of chlorine. The gas is rapidly absorbed, and enters into direct combination with the lime, although Dr. Ure thinks that no definite compound is formed.

Properties. A dry, white powder, similar to quick lime, having the odor of chlorine, which it readily yields up when moistened with water; possesses powerful bleaching properties, for which purpose it is extensively used in the arts. The strength of the chloride is estimated by the quantity of indigo which a given portion of the bleaching solution will deprive of its color. Used also in medicine, as a disinfecting agent; it should be kept in every family.

MAGNESIUM. Symb. Mg. Equiv. 12.7.

Magnesium was discovered and obtained in small quantities by Sir H. Davy, by means of galvanism; but M. Bussy, in 1830, obtained it in greater abundance by the action of potassium on chloride of magnesium.

Process. For this purpose, five or six pieces of potassium, of the size of peas, were introduced into a glass tube. The sealed extremity of which was bent into the form of a retort, and upon the potassium were laid fragments of chloride of magnesium; the latter being then heated to near its point of fusion, a lamp was applied to the potassium, and its vapor transmitted through the mass of the heated chloride. Vivid incandescence immediately took place; and on putting the mass after cooling into water, the chloride of potassium, with undecomposed chloride of magnesium was dissolved, and metallic magnesium subsided.—T.

Properties. A very malleable solid, of a white color like silver, and of a brilliant, metallic lustre. Dry air and water do not oxidize it, but moist air does; heated to redness in oxygen gas, it burns vividly and forms magnesia. In chlorine gas it inflames spontaneously.

Compounds of Magnesium.

Protoxide of Magnesium, Mg+O. 20.7, commonly known by the name of *magnesia*, is prepared by exposing the carbonate to a strong heat, to expel the carbonic acid.

Properties. A white, fusible powder of an earthy appearance, without taste or odor, sp. gr. 2.3; very infusible and sparingly soluble in water, requiring 5142 times its weight at 60°, and 36.000 of boiling water to dissolve it. The product is a hydrate. It changes vegetable infusions slightly, but possesses the properties of an alkali, by forming neutral salts with acids; absorbs water and carbonic acid from the air, and should be kept in close bottles. It exists in nature in serpentine, steatite, magnesite, and in sea-water, in considerable abundance.

Chloride of magnesium, Mg+Cl. 48.12, is prepared by dissolving magnesia in hydrochloric acid, evaporating to dryness, mixing the residue with its own weight of hydrochlorate of ammonia, and projecting the mixture in successive portions into a platinum crucible at a red heat. The ammonia is expelled, and the chloride remains a transparent, colorless mass; very deliquescent, and soluble in water and alcohol.

Iodide of Magnesium, Mg+I. 139, is formed by dissolving magnesia in hydriodic acid; known only in solution with water.

Bromide of magnesium, Mg+Br. 91 1, is prepared by dissolving magnesia in hydrobromic acid. It occurs in small acicular crystals, of a sharp taste, very deliquescent and soluble; it is decomposed by a strong heat.

Fluoride of magnesium. Mg+F. 31.38, is formed by digesting magnesia in excess of hydrofluoric acid, it is insoluble, and bears a red heat without decomposition.

SECT. 3. METALLIC BASES OF THE EARTHS.

ALUMINIUM. Symb. Al. Equiv. 13.7.

Sir H. Davy proved that *alumina* was an oxidized body, and Wohler succeeded in decomposing it, from which he obtained the pure metal, *aluminium*.

Preparation. This metal may be obtained by heating the chloride of aluminium with potassium in a covered platinum or porcelain crucible. Intense heat is evolved during the process. After cooling the mass, it is put into water, by which the saline matter is dissolved; hydrogen gas, of an offensive odor is evolved, and a grey powder subsides. This powder, after being washed in cold water, is pure *aluminium*.

Properties. Aluminium as thus prepared is a grey powder, similar to platinum, but when rubbed in a mortar, exhibits distinctly a *metallic lustre*. Fuses at a higher temperature than cast iron, and in this state is a conductor of electricity, but a non-conductor when cold.

Exp. Heated in the air to redness, it burns brilliantly and forms alumina, but when introduced into oxygen gas, at a red heat, it burns with such splendor, that the eye can hardly support the light, and with so much heat, that the resulting alumina is partially fused into yellow fragments, as hard as corundum, which not only scratch, but absolutely cut glass.

Exp. Takes fire in chlorine gas at a red heat, but is not oxidized by water at common temperatures, nor attacked by cold sulphuric, and nitric acids; soluble in solutions of potassa and ammonia, and in hot sulphuric, or dilute sulphuric and hydrochloric acids.

Compounds of Aluminium.

Sesqui-oxide of aluminium, $2Al+3O$. $27.4+24=51.4$, is the only known oxide of aluminium, and is commonly called *alumina*, or *aluminous earth*.

Natural History. Alumina is very abundant in nature, being found in every region of the globe, and in rocks of all ages. The different kinds of clay of which bricks, pipes, and earthern-ware are made, consist mostly of *hydrate of alumina*. It is also found beautifully crystallized, in some of the most beautiful gems. The ruby and the sapphire are nearly pure *alumina*.

Preparation. It may be prepared for chemical purposes from alum, which is a *sulphate of alumina and potassa*. Dissolve pure alum in water, and precipitate the alumina by carbonate of ammonia. This, when washed in hot water and filtered, is the *hydrate*, which may be rendered pure by a white heat. An easier process is to expose the sulphate of alumina and ammonia to a strong heat, so as to expel the ammonia and sulphuric acid. M. Gaudin has succeeded in forming rubies, by mixing ammoniacal alum with $\frac{1}{5000}$ part of chromate of potassa, and exposing to a high heat.

Properties. Inodorous, tasteless, and possesses the properties both of an acid and an alkali; insoluble in water, but has a powerful affinity for it; when moistened, it forms a ductile mass, which gives it its great utility in the arts. It is a remarkable exception to the law, that heat expands all bodies. There are probably several *hydrates of alumina.*

Uses. Used for bricks, and various kinds of pottery.

Sesqui-chloride of aluminium, $2Al+3Cl$. 133.66, was discovered by Wohler, by transmitting dry chlorine gas over a mixture of alumina and charcoal, heated to redness. It is of a pale, greenish-yellow color, partially translucent, of a highly crystalline lamellated texture, somewhat like talc, but without regular crystals. On exposure to the air, it fumes slightly, emitting an odor, like hydrochloric acid gas.

Exp. When thrown into water, it is speedily dissolved with a hissing noise, and so much heat is evolved, that the water, if in small quantities, is brought into a state of brisk ebullition, and forms the *hydrochlorate of alumina.*

Sesqui-sulphuret of aluminium, $2Al+3S$. 75.7, is prepared by droping a piece of sulphur on to aluminium, strongly heated. It is a vitrified, semi-metallic substance, of a dark color.

Sesqui-phosphuret of aluminium, $2Al+3P$. 74.5, is formed by heating aluminium in contact with the vapor of phosphorus; it is a blackish-grey pulverulent mass, which, by friction, acquires a dark grey metallic lustre, and in the air, has the odor of phosphuretted hydrogen.

Sesqui-seleniuret of aluminium, $2Al+3Se$. 146.2, is obtained by heating to redness a mixture of selenium and aluminium. It is a black pulverulent substance, which acquires a metallic lustre when rubbed.

GLUCINIUM. Symb. G. Equiv. 26.5. sp. gr. 3.

Glucinium was obtained by Wohler in 1828, by the action of potassium upon the *chloride* of glucinium. The process is similar to that for obtaining aluminium. It appears in the form of a grey powder, which acquires the metallic lustre by burnishing, and is easily oxidized.

Sesqui-oxide of glucinium, or *glucina*, $2G+3O$ .77, was discovered by Vanquelin in 1798. It is found only in the minerals *emerald*, *beryl*, and *euclase*.

Process. It is obtained by exposing beryl in fine powder, with three times its weight of carbonate of potassa, to a strong red heat. The fused mass is dissolved in dilute hydrochloric acid, evaporated to dryness, re-dissolved in acidulated water, and the alumina and glucina are thrown down by ammonia; the precipitate macerated by carbonate of ammonia which dissolves the glucina, and on boiling the filtered liquor, carbonate of glucina subsides; the carbonic acid is then expelled by a red heat.

Properties. A white powder, without taste or odor, quite insoluble in water. Pure potassa or soda precipitates it from its salts; distinguished from alumina, by being precipitated from its solution with carbonate of ammonia, when the solution is boiled.

YTTRIUM. Symb. Y. Equiv. 32.2.

Yttrium was prepared by Wohler, in 1828, by a process similar to that for obtaining glucinium.

Properties. It has a scaly texture, a greyish black color, and a perfectly metallic lustre. It is a brittle metal, and burns with splendor in common air, and with still greater brilliancy in oxygen gas. The result of this combustion is the earth *yttria*, which was discovered in 1794 by Gadolin, in a mineral at Ytterby, Sweden. It is of a white color, soluble in sulphuric acid, and combines with sulphur, selenium, and phosphorus. Its salts have a sweetish taste, and some of them have an amethystine color.

THORIUM. Symb. Th. Equiv. 59.6.

This metal was procured by the action of potassium on the chloride of thorium; decomposition being accompanied by a slight detonation. On washing the mass, thorium is left, in the form of a heavy, metallic powder, of a deep leaden grey color, and when pressed in an agate mortar, it acquires metallic lustre and an iron grey tint.—T.

Properties. Thorium is not easily oxidized at common temperatures, but burns with great brilliancy in the air. It is not acted upon by alkalies, scarcely at all by nitric, and slowly by sulphuric acid; but is readily dissolved by hydrochloric acid, with the disengagement of hydrogen gas.

Protoxide of thorium, or *thorina*, ThO. 67.6, was discovered by Berzelius in 1828, in a rare mineral from Norway, called *thorite.* It is a white, earthy substance, soluble in none of the acids, except the sulphuric, and is precipitated from its solutions by the caustic alkalies as a *hydrate*, in which state it absorbs carbonic acid from the atmosphere, and dissolves in acids.

It is distinguished from alumina and glucina, by its insolubility in pure potassa, and from yttria, by forming with sulphate of potassa a double salt, insoluble in a cold, saturated solution of sulphate of potassa.

ZIRCONIUM. Symb. Zr. Equiv. 33 7.?

Zirconium was discovered by Berzelius in 1824. It is obtained by heating the double fluoride of zirconia and potassa, carefully dried and mixed with potassium in a glass or iron retort. The mass is then washed in hot water, and digested for some time in hydrochloric acid.

Properties. This substance exists in the form of a black powder. It may be pressed out into thin shining scales, but its particles adhere very slightly. It is a non-conductor of electricity. It takes fire when heated in the open air, at a temperature below a red heat; the product is *zirconia.*

Sesqui-oxide of zirconium, or *zirconia*, 2Zr+3O. 91.4, was discovered by Klaproth in 1789, from the Zircon, or Jargon of Ceylon; 17 parts of this substance finely pulverized and mixed with 21 of litharge, may be fused, and a glass obtained, soluble in acids, from which the zirconia is derived, or it can be formed directly by the combustion of the metal.

Properties. A fine, white powder, inodorous, and tasteless, sp. gr. 4; exposed to a strong heat it fuses, assuming a light grey color; when cool, it is so hard as to strike fire with steel, and to scratch quartz crystal.

SECT. 4. METALS, THE OXIDES OF WHICH ARE NEITHER ALKALIES NOR EARTHS.

1. *Metals which decompose water at a red heat.*

MANGANESE. Symb. Mn. Eq. 27.7. Sp. gr. 8.013.

In 1774, Scheele described the black oxide of manganese as 'a peculiar earth.' Gahn subsequently discovered that it contained a new metal, to which he gave the name of *magnesium*, a term applied afterwards to the metallic base of magnesia; and for which the words *manganesium* and *manganium* have been substituted. The metal is not found in the native, or uncombined state, but its oxides are very abundant.

Preparation. Make a paste with finely pulverized oxide of manganese and oil, and expose it to the heat of a smith's forge, in a Hessian crucible, lined with charcoal, for the space of two hours.

Properties. A hard, brittle metal, of a greyish white color and granular texture, *very infusible*, not attracted by the magnet, except when it contains iron; soon tarnishes on exposure to the air, and absorbs oxygen rapidly when heated to redness. Decomposes water slowly at common temperatures, but rapidly at a red heat.

Compounds of Manganese.

Protoxide of manganese, Mn+O. 35.7, may be formed as shown by Berthier, by exposing the peroxide, sesqui-oxide, or red oxide of manganese to the combined agency of charcoal, and a white heat; or by exposing either of the oxides contained in a glass tube, to a current of hydrogen gas, at an elevated temperature.

Properties. When pure, it is of a light green, or mountain green color, undergoing little if any change in the open air, but oxidizes rapidly at 600° Far., and is instantly converted into the red oxide, at a low red heat, and sometimes takes fire. It is the salifiable base of the metal, and is contained in all its salts; hence its strong affinity for acids.

Sesqui-oxide of manganese, $2Mn+3O$, or $Mn+1\frac{1}{2}O$. 79.4, occurs nearly pure in nature, and may be formed by exposing the peroxide to a red heat. It is the chief residue of the usual process of obtaining oxygen gas, but it is difficult to regulate the heat so as to obtain it in a pure state.

Properties. The color is brown or black, according to the source from which it is obtained; unites with nitric and sulphuric acids, and is converted by exposure to the air, into the peroxide.

Peroxide of manganese. $Mn+2O$. 43.7. This is a well known native product, commonly called *black oxide of manganese.*

Properties. It occurs generally in masses, of an earthy appearance, and black color, mixed with other substances; but it is frequently found in small prismatic crystals. It is not affected by exposure to the air or water, but yields oxygen when heated to redness, and is the substance most generally employed for that purpose (see page 120); does not unite with acids or alkalies.

Uses. Employed in the arts for coloring glass, in preparing chlorine gas, and in forming the salts of manganese.

Red oxide of manganese. $3Mn+4O$. 115.1. This is identical with the *oxidum manganoso-manganium* of Arfwedson, and occurs as a natural product. It may be formed artificially by exposing the peroxide or sesqui-oxide to a white heat; color when finely rubbed, is nearly black, when warm, and brownish-red when cold. It is permanent in the air at all temperatures; dissolves in small quantities by cold sulphuric acid, and more rapidly by the aid of chlorine; the solution has an amethystine tint. It is the cause of the rich color of the amethyst.

Varvicite. $4Mn+7O$. 166.8. Sp. gr. 4.531. Known only as a natural production, and first noticed by Mr. Phillips among some ores of manganese, found at Hartshill in Warwickshire. It resembles the peroxide in color, for which it was first mistaken, but may be distinguished from it, by its stronger lustre, greater hardness, more lamellated texture, and by yielding water when heated to redness. It is probably like the red oxide, a compound of two oxides, consisting of two equivalents of the peroxide, and one of the sesqui-oxide of manganese, with one of water.—T.

Manganic acid. $Mn+3O$. 51.7. When peroxide of manganese is mixed with equal weights of nitre, or carbonate of potassa, and heated to redness, it fuses, and a green-colored mass is formed, known by the name of *mineral chameleon*, from the property of its solution to pass through several shades of color.

Exp. On the addition of cold water, a green solution is formed which soon becomes *blue, purple and red*, and ultimately a brown, flaculent matter, hydrated peroxide of manganese subsides.—T.

These changes are owing to the formation of manganate of potassa, of a green color, which passes to the per-manganate of potassa, which is red, the blue and purple being due to a mixture of these compounds; but the manganic acid has not been obtained in a separate state, owing to its ready decomposition.

Permanganic acid. $2Mn+7O$. 111.4. This acid is more permanent, though easily decomposed, even by contact with paper or linen in filtering. It may be obtained from the permanganate of baryta, by sulphuric acid.

Properties. Color red; decomposed by water at 86°; coloring matter is bleached by it, but particles of organic matter floating in the air, decompose it rapidly.

Proto-chloride of manganese, $Mn+Cl$. 63. 12, is prepared by evaporating a solution of the chloride to dryness, and heating it to redness in a glass tube, while a current of hydrochloric acid gas is transmitted through it. Fuses at a red heat, and forms a pink-colored lamellated mass on cooling. Deliquescent and very soluble in water.—T.

Per-chloride of manganese, $2Mn+7Cl$. 303.34, was discovered by Dumas, and formed by putting a solution of per-manganic, into sulphuric acid, and adding fused sea-salt.

Properties. When first formed it is a greenish-colored vapor, but by passing it through a glass tube cooled to –5°, it condenses into a greenish-brown liquid, decomposed instantly by water.

Per-fluoride of manganese, $2Mn+7F$. 186.16, was discovered by Dumas and Wohler. Prepared by mixing the mineral chameleon with half its weight of fluor-spar in a platinum vessel, and decomposing the mixture with fuming sulphuric acid.

Properties. A yellowish-green gas, or vapor, which acquires a beautiful purple-red color when mixed with air; freely absorbed by water, giving to the solution, the same red tint; acts on glass with the formation of fluo-silicic acid gas, and the deposition of a brown matter which acquires a deep purple red tint by the addition of water.

Proto-sulphuret of manganese, $Mn+S$. 43.8, is found native in Cornwall, Eng. and may be formed by igniting the sulphate with one sixth of its weight of charcoal, in powder.

Cyanuret of manganese, $Mn+Cy$. 27.7+26.39=54.09. Equiv.

Phosphuret and carburet of manganese, may be obtained by heating the metal in contact with phosphorus or carbon.

Alloys of manganese. Manganese unites with several of the metals, forming alloys of little importance.

IRON. Symb. Fe. Equiv. 28. Sp. gr. 7.78.

History. Iron is decidedly the most important and useful of the metals. It appears essential to a state of civilization, hence it is the most abundant, and widely diffused throughout different parts of the earth. Hence, too, it seems to have been made known to the first inhabitants of the earth, and used in all ages where men have emerged even to the state of barbarians. It was formerly called *Mars*.

Natural History. Iron is rarely found pure in nature. Even meteoric iron is alloyed with cobalt and nickel, but its oxides are very abundant. In combination with oxygen and sulphur, it is so widely diffused, that few minerals can be found that do not contain traces of it. It enters also into plants and animals. The ores of iron are the red oxides, including red and brown hemetite; the black oxide or magnetic iron ore, and the carbonate of the protoxide, either pure or in the form of clay iron ore.

Process. The extraction of the iron from the ores is effected, by subjecting them after being roasted and reduced to a coarse powder, to the action of charcoal, lime and caloric; this is the cast-iron, which contains some impurities, especially carbon. The malleable or wrought-iron is prepared from this, by continuing the process until the carbonaceous matter is burned out; it then becomes solid again, and is put under a roller or hammer and drawn out into bars. *Steel* is the wrought-iron combined with carbon. The best wrought-iron bars are surrounded by dry charcoal and heated to a high temperature.

Properties. Iron has a peculiar grey color, and strong metallic lustre which is brightened by polishing, of which it is capable of receiving a higher degree than any other metal. It is less ductile and malleable than some others, but the most tenacious of all; hence it may be drawn out into fine wire, but not into their leaves. Its texture is fibrous, and when heated is soft, and possesses the property of being welded to other heated iron. When cooled suddenly it is brittle, but may be rendered malleable again by heat; it is very infusible, and when combined with carbon, very hard. In this state, it is capable of being made permanently magnetic,—it is the great repository of natural magnets, and the only substance, save cobalt and nickel, which possesses magnetic properties.

Its uses in the arts are well known.

Protoxide of iron. $Fe+O$. 36. The existence of this oxide was first inferred by Gay Lussac, but Stromeyer obtained it in an insulated form, by transmitting dry hydrogen gas over the protoxide at a low temperature. It may also be precipitated from its salts as a white hydrate by pure alkalies, as a carburet by alkaline carbonates, as a white fero-cyanuret by fero-cyanuret of potassium, and as a proto-sulphuret by alkaline hydro-sulphates.

Properties. Color dark blue, and communicates a blue tint to substances melted with it. It is magnetic, and so combustible, that it takes fire spontaneously in the open air, and is converted into the peroxide. Its salts absorb oxygen so rapidly from the air, as to be useful in eudiometry. It is the base of the native carbonate, and the *green vitriol* of commerce.

Peroxide of Iron. $2Fe+3O$ or $Fe+1\frac{1}{2}O$. 80. This is the *red hemetite* of mineralogists, a very abundant natural production.

It is made chemically by dissolving iron in nitro-hydrochloric acid, and adding an alkali.

The precipitate is of a brownish color, and is identical with the mineral called *brown hemetite*, and consists of one equivalent of the peroxide, and two of water.

Properties. It is a brownish-red compound, not attracted by the magnet. It is precipitated from its salts by the pure alkalies, with fero-cyanuret of potassium it forms *Prussian blue*, with infusion of nutgalls it forms ink.

Tests of the presence of iron in any composition, may be made by boiling it with nitric acid, which converts the iron into the peroxide; the fero-cyanuret of potassium will then form a blue precipitate.

Black oxide. (Fe+O)+(2Fe+3O.) 116. This compound is called by Berzelius, *oxidum ferroso-ferricum*, and is supposed to be a mixture or combination of the two preceding oxides.

It occurs native, often in regular octohedral crystals. It is formed also when iron is heated in the open air, or in contact with moisture. It is not only magnetic, but is itself often a magnet. With sulphuric acid, an olive-colored solution is formed containing two salts, the sulphate of the protoxide, and peroxide, which may be separated from each other by means of alcohol. The black oxide is the cause of the green color of glass.

Proto-chloride of Iron, Fe+Cl. 63.42, is formed by dissolving iron in hydrochloric acid, evaporating to dryness, and heating the product to redness, in a tube deprived of air. It is a grey, crystalline substance, fusing at a red heat, and is easily converted into the hydrochlorate of the protoxide of iron.

Per-chloride of iron, 2Fe+3Cl. 162.26, is formed by the combustion of iron in chlorine gas. It is a yellowish-brown substance, crystallizes in small irridescent plates, of a red color; volatilizes at little above 212°; deliquesces readily, and dissolves in water, alcohol, and ether, and is converted by water into the hydrochlorate of the peroxide of iron.

Protiodide of iron, Fe+I. 154.3, is prepared by digesting iodine in water and iron wire. On evaporating the solution to dryness, without exposure to the air, and heating it moderately, it yields crystals of an iron-grey color and metallic lustre, deliquescent, very soluble in water and alcohol, and used in medicine as a tonic.

The periodide of iron, 2F+3I. 434.9, isobtained by exposing a solution of the protiodide to the air. It is a volatile, red compound, soluble in water and alcohol.

The proto-bromide of iron, Fe+Br. 106.4, and the *per-bromide of iron*, 2Fe+3Br. 291.2, are formed in a similar manner with the iodides, and have similar properties. *Proto-fluoride of iron*, Fe+F. 46.68.

Per-fluoride of iron, 2Fe+3F. 112.04, is formed by dissolving peroxide of iron in hydrofluoric acid. As the acid becomes saturated, crystals are formed in small, white, square tables, which are sparingly soluble in water.

Proto-sulphuret of iron, Fe+S. 44.1, is prepared by heating equal parts of sulphur and iron-filings in a covered Hessian crucible; considerable heat is evolved, and a yellowish-grey substance is formed; this is completely dissolved, if pure, by dilute sulphuric acid, yielding hydro-sulphuric acid. It exists in nature, in the *variegated copper pyrites*, and forms a black precipitate, when hydro-sulphate of ammonia is mixed with the sulphate of the protoxide of iron.

Sesqui-sulphuret of iron, 2Fe+3S. 104.3, is formed by the action of the hydrosulphuric acid on the hydrated peroxide of iron.

It has a yellowish-grey color, and dissolves in dilute sulphuric and hydrochloric acids, with the formation of hydrosulphuric acid and bisulphuret of iron.

Bisulphuret of iron. Fe+2S. 60.2. This is the *iron pyrites* of mineralogists, and occurs abundantly in cubes, or in some analogous form, of a yellow color, and metallic lustre; sp. gr. 4.981; so hard as to strike fire with steel; hence its name.

It is dissolved by nitro-hydrochloric acid, but by no other acid, except the nitric. By heat, it is converted into magnetic iron pyrites, if in close vessels, but exposed to the air, into the peroxide of iron.

Magnetic iron pyrites. (5Fe+S)+(Fe+2S.) 280.7. This natural product appears to be composed of five equivs. of the proto-sulphuret, and one of the bisulphuret. It may be formed as above. It is much more easily oxidized than the bisulphuret.

Tetra-sulphuret of iron, 4Fe+S. 128.1, and the *disulphuret of iron*, 2Fe+S. .72, may be formed by passing hydrogen gas at a red heat, over the anhydrous sulphate of the protoxide of iron, to obtain the disulphuret, and over the disulphate of the peroxide of iron, for the tetra-sulphuret.

Properties. They exist in a greyish-black powder, soluble in dilute sulphuric acid, with the evolution of hydrogen and hydrofluoric acid gases.

Diphosphuret of iron, 2Fe+P. 71 7, is prepared by heating the phosphuret in a covered crucible, lined with charcoal.

Properties. It is a fused, granular substance, which resembes iron in color and lustre, but is very brittle, and renders iron brittle, when contained in it, as it sometimes is.

Perphosphuret of iron, 3Fe+4P. 146.8, is obtained by the action of phosphuretted hydrogen on sulphuret of iron, and resembles the preceding, in most of its properties.

Carburets of iron. Carbon and iron unite in several proportions; only three seem worthy of notice, graphite, cast or pig iron, and steel.

Graphite is known as a natural product, under the names of *plumbago* and *black-lead.* There is not more than 10 per cent. of iron, and often not five. Used for pencils, crayons, crucibles, and for burnishing iron.

Cast iron is a compound of carbon and iron, and is the product of melting the ores of iron with charcoal. Its uses are well known.

Steel is formed by filling a furnace with bars of the best malleable iron, with layers of charcoal between, and subjecting them to strong heat away from the air; about 1.3 to 1.75 per cent. of carbon combines with the iron. This is the substance used for the various purposes of the arts. It is much harder than iron, but more brittle, also less ductile and malleable, but more firm in its texture, and capable of a higher polish. By fusion it forms *cast-steel.*

Proto-cyanuret of iron, $Fe+Cy$. 54.39, is prepared by mixing in solution, cyanuret of potassium with sulphate of protoxide of iron; on exposure to the air, it passes to *Prussian blue.*

Proto-sulpho-cyanuret of iron, $Fe+CyS^2$. 86.59, is obtained by dissolving iron in hydro-sulpho-cyanuric acid, and evaporating the pale green solution to dryness *in vacuo.*

Sesqui-sulpho-cyanuret of iron, $2Fe+3CyS^2$. 231.77, is prepared by mixing the sulpho-cyanuret of potassium, with any salt of the peroxide of iron. It has a blood-red color, and is a very delicate test of the presence of iron.

ZINC. Sym. Zn. Equiv. 32.3. Sp. gr. 7.00.

Zinc has long been known in the east, India and China, but was first distinctly noticed in the sixteenth century, by Paracelsus, under the name of *zinetum.* Henckel is the first who obtained the metal from Calamine, in the year 1721. Von Swab first obtained it by distillation in 1742; and Margraff published a process in the Berlin Memoirs in 1746.

Natural History. Zinc, like most of the metals, is rarely found pure in nature, but is an abundant substance in combination with oxygen, carbon and sulphur.

Process. Commercial zinc or spelter, is generally obtained from calamine, native carbonate of zinc, or from the native sulphuret, called by mineralogists, *zinc blende.* This is oxidized by heating it in the open air, called *roasting.* It is then distilled; that is, it is heated in a crucible open at the bottom and closed at the top, to which is affixed a tube, which terminates just above a basin of water; the gaseous products with the vapor of zinc pass through the tube, and the zinc is condensed. The first portions are impure, containing cadmium and arsenic, which give the brown blaze; when the blue blaze is seen, the zinc is collected. It contains now some impurities, which are removed by a white heat in an earthen retort, to which a receiver full of water is adapted.

Properties. This metal is blueish white, with a strong metallic lustre and lamellated texture; it is a hard and brittle metal, but between the temperatures of 210° and 300° Far. it is malleable and ductile, and in this state is rolled out into plates; fuses at 773° Far. and when slowly cooled, crystallizes in four or six-sided prisms. It is easily pulverized when heated to a certain temperature below redness, and sublimes at a high temperature in close vessels, without change.

Uses. Zinc is used extensively in the arts, for the construction of voltaic instruments, and for covering buildings. It has been proposed to use it for culinary vessels, water-pipes and sheathing for ships; but it is so easily oxidized and acted upon by the weakest acids, that it is unfit for these uses.

Compounds of Zinc.

Protoxide of Zinc. Zn+O. 40.3. This is the only known oxide of zinc, formerly called *flowers of zinc*, *nihil album*, and *philosopher's wool.*

It is obtained by the combustion of zinc in the open air, in oxygen gas, or by heating the carbonate to redness. It is found native in Franklin, New Jersey.

The hydrated oxide of zinc may be obtained by uniting a rod of iron and zinc, and placing them in caustic ammonia in a close vessel.

Properties. At common temperatures it is white, but assumes a yellow color when heated to redness; insoluble in water, and is a strong salifiable base.

The oxide is precipitated from its solutions, as a white hydrate, by pure potassium and ammonia, and as a carbonate by alkaline carbonates. The oxide is sometimes substituted for white lead for paint; it is more durable but not so white.

Berzelius describes a sub-oxide, and Thenard a binoxide, but they are doubtful substances.

Chloride of zinc, Zn+Cl. 67.72, is formed by burning zinc filings in chlorine. It is colorless, fusible a little above 212°, and has so soft a consistency, at common temperatures, as to be called *butter of zinc*.

Iodide of zinc, Zn+I. 158.6, is prepared by digesting iodine in water with zinc filings.

Bromide of zinc, Zn+Br. 110.7, is formed in a similar manner with the preceding.

Fluoride of zinc, Zn+F. 50.98, is prepared by the action of hydrofluoric acid on the oxide of zinc. It exists as a white solid.

Sulphuret of Zinc, Zn+S 48.4, is a native product, known by the name of *zinc blende*. It may be formed by heating sulphur with the oxide; it crystallizes in dodecahedrons; lamellated structure; adamantine lustre; color red, yellow, brown or black. *Cyanuret of Zinc*, Zn Cy. 58.69.

CADMIUM. Symb. Cd. Equiv. 55.8. Sp. gr. 8.604.

History. Cadmium was discovered in 1817, by Stromeyer of Göttingen, in an oxide of zinc which had been prepared for medical use. Dr. Clark detected it in the zinc ores of Derbyshire, and in the common zinc of commerce, and Mr. Herapath found it in considerable quantities in the zinc works near Bristol, England.

Process. The following is the process of Stromeyer. The ore of cadmium is dissolved in hydrochloric or sulphuric acid in excess. The sulphuret of cadmium is precipitated by hydrosulphuric acid. Nitric acid decomposes this, and forms a nitrate, which is evaporated to dryness. To a solution of this in water, an excess of carbonate of ammonia is added, and the white carbonate of the oxide of cadmium is precipitated, which, when subjected to a red heat, yields a pure oxide. The metallic cadmium is obtained from the oxide, by heating it with charcoal.

Properties. Cadmium resembles tin in its color and lustre, but is harder and more tenacious; very ductile and malleable; melts at about the same temperature as tin, and is nearly as volatile as mercury; heated in the open air it absorbs oxygen, and is converted into the

Oxide of cadmium, Cd+O. 63.8, which is the only known oxide; is a strong alkaline base, forming neutral salts with acids; insoluble in water; fixed in the fire; and precipitated by all the alkaline carbonates, and by pure ammonia and potassa.

Chloride of cadmium. Cd+Cl. 91.22. This compound is formed by dissolving oxide of cadmium in hydrochloric acid. By concentration, the chloride crystallizes in four-sided rectangular prisms, which lose their water of crystallization by heat, and even in dry air; fused below redness, and sublimes at a high temperature.

Iodide of cadmium, Cd+I. 182.1, is formed in the same way as the iodide of zinc; soluble in water and alcohol, and crystallizes in large, colorless, transparent, hexagonal tables, which do not change in the air, and have a pearly lustre. By heat they lose water, and then fuse.

Sulphuret of cadmium, Cd+S. 71.9, occurs in nature in zinc blende, and is prepared by the action of hydrosulphuric acid on the salts of cadmium. It has a yellowish orange-color, and may be distinguished from the sulphuret of arsenic, by being insoluble in pure potassa, and by sustaining a white heat without subliming.

Phosphuret of cadmium, is a grey compound, very brittle and fusible.

TIN. Symb. Sn. Equiv. 57.9. Sp. gr. 7.2.

Tin was known to the ancients, in the time of Moses; and was obtained, chiefly from Cornwall, England, and Spain, at a very early period by the Phenicians.

Process. The tin of commerce is obtained from the native oxide by heat and charcoal, and in the form of black and grain tin.

Stream tin is the native oxide of Cornwall, which is found in rounded pebbles, occasioned by the action of water. Tin is seldom perfectly pure, containing a little copper, iron and arsenic. That from Malacca is the purest. *Tin foil* is

Properties. It occurs in crystalline scales, of a golden-yellow color and metallic lustre; soluble in pure potassa, and its only solvent among the acids, is the nitro-hydrochloric acid. It is obtained as a hydrate by the action of hydro-sulphuric acid, and the bichloride of tin in solution.

Ter-phosphuret of tin, $Sn+3P$. 105, is formed according to Rose, by the action of phosphuretted hydrogen on a solution of proto-chloride of tin. It oxidizes rapidly in the air.

COBALT. Symb. Co. Equiv. 29.5. Sp. gr. 7.834.

Cobalt was discovered by Brandt, and derives its name, *Kobold, an evil spirit*, from the belief of the German miners, that its presence was unfavorable to that of valuable metals.

Natural History. It exists in nature generally in combination with arsenic. It is also a constant ingredient in meteoric iron, and is found combined with sulphur and other combustibles.

Process. It may be obtained from the oxide by heating it in connection with charcoal, and then passing over it a stream of hydrogen gas, to combine with the oxygen.

Properties. Cobalt is a brittle solid, of a reddish-grey color, and weak metallic lustre. Fuses at 130° Wedgewood, and crystallizes when slowly cooled. It is attracted by the magnet, and is susceptible of being rendered permanently magnetic; absorbs oxygen, when heated in open vessels. It is also oxidized by nitric acid, and decomposes water at a red heat.

Compounds of Cobalt.

Protoxide of cobalt, $Co+O$. 37.5, is obtained by decomposing the carbonate by heat, in a vessel from which the air is excluded.

Properties. It has an ash-grey color, and is the base of all the salts of the metal, most of which are a pink-blue. When heated, it absorbs oxygen, and is converted into the peroxide. It is distinguished by giving a blue tint to borax when melted with it.

Zaffre is an impure oxide of cobalt, obtained by heating the arseniuret in a reverbatory furnace. When this substance is heated with sand and potassa, a beautiful blue-colored glass is formed, known by the name of *smalt*, and used in the arts for communicating the blue color to glass, porcelain and earthen-ware.

The protoxide is easily precipitated from its salts by alkalies, the precipitates are of a blue or pale-pink color; dissolved in excess of alkali.

$\frac{4}{3}$ *Oxide of cobalt*, $3Co+4O$. 120.5, is probably a compound of the peroxide and the protoxide.

Peroxide of cobalt, $2Co+3O$. 83, is obtained as a black hydrate with 2 equivs. of water, when chloride of cobalt is decomposed by chloride of lime. The water is driven off by exposure to a heat of 600° or 700°. It combines with none of the acids, and when strongly heated, is decomposed and resolved into the protoxide and oxygen.

Chloride of cobalt, $Co+Cl$. 64.92, is obtained by dissolving metallic cobalt or either of its oxides in hydrochloric acid. The solution is of a pink color, and yields on evaporation small crystals of the same color. When these crystals are deprived of their water of crystallization, they assume a blue color, a property on which is founded its use as a *sympathetic ink.*

Exp. Write on paper with a dilute solution of the chloride, and expose it to a gentle heat, it becomes blue. This solution is called *Hillot's sympathetic ink*, and is described by some chemists as a *muriate* of cobalt; but Turner thinks it a *chloride*, analogous to several other compounds, generally described as *muriates* of the metals.

Sulphurets of cobalt. Cobalt unites with sulphur in three proportions.

The proto-sulphuret, $Co+S$. 45.6, is formed by throwing fragments of sulphur on red-hot cobalt; has a grey color, a metallic lustre, and crystalline texture.

The sesqui-sulphuret of cobalt, $2Co+3S$. 107.3, is formed by passing a current of hydrosulphuric acid gas, over the *oxy-sulphuret* at a red heat.

The bisulphuret, $Co+2S$. 61.7, is prepared by heating below redness, in a glass tube, two parts of the carbonate of the oxide of cobalt, intimately mixed with three of sulphur.

Sub-phosphuret of cobalt, $3Co+2P$. 119.9, is obtained by the action often an alloy of tin and lead. ***Block tin*** is less pure than grain tin.

Properties. Tin has a color and lustre resembling silver. It is very malleable. Tin foil does not exceed $\frac{1}{1000}$ of an inch in thickness, but its ductility and tenacity is inferior to many of the metals. When bent backward and forward, a crackling noise is produced, by which it may be readily distinguished from lead, zinc, etc. It fuses at 240° Far. When heated to whiteness, it takes fire. If a drop of the fused tin fall upon a board, it will divide into several globules, and burn with a beautiful white light. The brilliancy of its surface tarnishes slowly when exposed to the air at common temperatures, but oxidizes at a high temperature.

Compounds of Tin.

Protoxide of tin, $Sn+O$. 65.9. sp. gr. 6.666, is formed by fusing tin for some time in an open vessel, or it may be precipitated as a hydrated oxide, from a solution of chloride of tin, by an alkaline carbonate.

Properties. It is a grey powder, permanent in the air, unless touched by a red hot body, when it takes fire and is converted into the peroxide; it is dissolved in the strong acids, and the pure, fixed alkalies. It readily absorbs oxygen from the air and other compounds, hence it throws down mercury, silver and platinum, from their salts. With gold, it causes the *purple precipitate of Cassius;* by this character it is readily distinguished. It is precipitated from its solutions by hydro-sulphuric acid as a black proto-sulphuret.

Sesqui-oxide of tin, $2Sn+3O$. 139.8, is prepared by mixing recently precipitated and moist hydrated peroxide of iron, with a solution of proto-chloride of tin. The sesqui-oxide is precipitated in a slimy, grey matter, of a yellowish tint from oxide of iron; distinguished from the protoxide by being soluble in ammonia.

Binoxide of tin, $Sn+2O$. 73.9, is prepared by the action of nitric acid on metallic tin. The concentrated acid does not act on the tin, but on the addition of water violent effervescence takes place, and a white powder, the hydrated binoxide of tin is formed. The water is expelled by heat, and the pure binoxide, of a straw-yellow color, results. The hydrated oxide may also be precipitated from the proto-chloride by potassa, ammonia, or the alkaline carbonates; but the properties differ from that formed in the other way, the latter being dissolved in the strong acids, while the former is not. It acts the part of a feeble acid, uniting with the pure alkalies, and forming a class of compounds, the *stannates.*

Binoxide of tin is recognized by its being precipitated from its solutions by hydrochloric acids as a bulky hydrate, and by any of the alkalies or alkaline carbonates. When melted with glass it forms a white enamel.

Proto-chloride of tin, $Sn+Cl$. 93.32, is obtained by distilling equal weights of tin and bichloride of mercury. It is a grey solid of resinous lustre; fuses below redness, and sublimes at a high temperature; crystallizes in small, white needles. A solution of the proto-chloride may be prepared for deoxidizing purposes, by heating granulated tin in strong hydrochloric acid, as long as hydrogen gas is evolved.

Bichloride of tin, $Sn+2Cl$. 128.74, is formed by distilling eight parts of granulated tin with twenty-four of bichloride of mercury, or by heating the proto-chloride in chlorine gas.

Properties. It is a colorless liquid, very volatile, yielding white fumes in an open vessel, hence formerly called the *fuming liquor* of Libavious; boils at 248°; sp. gr. of its vapor, 9.1997; mixed with $\frac{1}{3}$ of its weight of water, it forms a solid hydrate, but dissolves in a larger quantity of water.

Uses. The solution called *per-muriate of tin,* is used in dying, and is prepared by dissolving tin in nitro-hydrochloric acid.

Protiodide of tin, $Sn+I$. 184·2, is prepared by heating granulated tin with $2\frac{1}{2}$ times its weight of iodine. It is a brownish-red substance, very fusible, volatile, and soluble.

Biniodide of tin, $Sn+2I$. 310.5, is prepared by dissolving the hydrate of the peroxide, precipitated by alkalies from the bichloride, in hydriodic acid. It forms yellow crystals of a silky lustre.

Proto-sulphuret of tin, $Sn+S$. 74, is prepared by pouring melted tin upon its own weight of sulphur, and stirring rapidly with a stick. It has a blueish grey or nearly black color, and metallic lustre; fuses at red heat, and has a lamellated texture when cool.

Sesqui-sulphuret of tin, $2\,Sn+3S$. 164.1, is obtained by heating to low redness, the proto-sulphuret with $\frac{1}{8}$ of its weight of sulphur. It is a deep greyish-yellow compound.

Bisulphuret of tin. $Sn+2S$. 90.1. This compound was formerly called *Mosaic gold,* and may be prepared by heating a mixture of two parts of peroxide of tin, two of sulphur, and one part of hydrochlorate of ammonia, in a glass or earthen retort, to a low, red heat, till sulphurous acid ceases to be evolved.

empty crucible, which is placed over the other, and kept cool for the purpose of condensation.

Properties. Arsenic is a very brittle metal, of a steel-grey color, high metallic lustre, and of a crystalline structure. When heated to 356°, it sublimes without fusion, and may be collected in close vessels without change, but when thrown on a red hot iron, it burns with a blue flame, and white smoke, giving off a strong odor of garlick, a property which belongs to no other metal unless it be zinc; when thus heated, in the open air, it is converted into the white oxide of arsenic. Exposed at common temperatures of the air, it oxidizes slowly, forming the substance called *fly-powder*, which is a mixture of the oxide and the metal.

Arsenic detonates with some of the salts and decomposes them.

Exp. Take three parts of chlorate of potassa, and one of arsenic, finely powdered, and cautiously mixed together.
1. Place a small quantity on an anvil, and strike it with a hammer; the arsenic will instantly combine with the salt, producing an explosion with flame.
2. Set it on fire, and it will burn rapidly.
3. Throw it into concentrated sulphuric acid, and a bright flash of light will be perceived at the moment of contact.

Uses. Arsenic is used in the arts. It renders glass white.

Compounds of Arsenic.

Arsenious acid, $2As+3O$. 99.4, commonly called *white arsenic*, and *white oxide of arsenic*, may be formed by the combustion of the metal; but the white arsenic of commerce is obtained from the *arseniurets* of *cobalt*, by sublimation.

Properties. Arsenious acid is white, semi-transparent, and when first formed, of a vitreous lustre and conchoidal fracture. Its acid taste is owing to the inflammation which it produces; it has a faint impression of sweetness. Its sp. gr. is 3.7; has two crystalline forms, but is usually found in six-sided scales, derived from a rhombic prism; soluble in water.

It is one of the most virulent poisons known, and as it is sometimes accidentally or intentionally taken, it is a frequent cause of death, and a subject of judicial investigation. Hence the importance of pointing out the most effectual modes of detecting its presence.

Tests. The most valuable are the *ammoniaco-nitrate of silver*, *ammoniaco-sulphate of copper*, *hydrosulphuric acid*, and *hydrogen gas*.

1. Obtain as large a quantity of the liquid from the stomach as possible. This, with parts of the stomach, should be put into pure water, filtered and evaporated, so as to obtain a concentrated solution; add to this, ammoniacal nitrate of silver,* and if arsenic is present, a yellow, arseniate of silver will be thrown down.

2. Add to the suspected liquid, ammoniacal sulphate of copper,† and a green precipitate will be formed, called *Scheele's green*.

3. Pass into the liquid, hydrosulphuric acid, and if arsenious acid is present, orpiment, or the sesqui-sulphuret of arsenic will be formed, giving to the liquor a yellow, turbid appearance. This sulphuret should then be dried, mixed with black flux, carefully introduced into a glass tube, and heated by a spirit-lamp; the sulphuret will be decomposed and metallic arsenic appear on the cool parts of the tube. This is a very satisfactory test; but if on heating the substance thus deposited, it rises up in white fumes, with an alliaceous odor, and is deposited in white, octohedral crystals, we may be sure that arsenic is present.

4. Introduce a quantity of the suspected liquid into a Florence flask, having a jet pipe and a stop-cock attached, with zinc and sulphuric acid; the water will be decomposed, and the nascent hydrogen, in passing through the water containing arsenious acid, will form arseniuretted hydrogen; and on burning the gas, as it issues from the jet, metallic arsenic will be deposited on a plate of glass or porcelain, held over the flame.

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* Prepared by dropping into a strong solution of nitrate of silver ammonia, till the oxide of silver, first precipitated, is nearly all dissolved.

† Prepared in the same way with the preceding, by using the sulphate of copper, instead of the nitrate of silver.

Any one of these tests, however, should not be depended upon in a case where the life of a fellow being is at stake, as other metals, such as antimony, will sometimes present a similar appearance; but if the suspected substance be tested by each of the four ways mentioned, there can be no doubt but that it contains arsenious acid.

Its action upon animals, whether taken into the stomach, or applied to wounds, is attended by pain and vomiting, and if life be prolonged beyond twenty-four hours, diarrhœa, a sensation of heat, and extreme pain in the stomach and intestines succeed, pulse feeble, countenance anxious, skin livid, often attended by eruptions.

The best antidote is per-hydrate of iron, with a small quantity of ammonia. In cases rapidly fatal, extreme faintness, cold sweats, attended with slight convulsions are experienced. (See Christison on Poisons.)

Arsenic has the property of preserving from decay the bodies of those poisoned with it. The stomach and intestines have thus been found entire two years and a half after death.

Arsenic acid, $2As+5O$. 115.4, is formed by dissolving arsenious acid in concentrated nitric, mixed with a small quantity of hydrochloric acid, distilling in a glass vessel until it acquires the consistency of syrup, and then heating nearly to redness, in a platinum crucible, to expel the nitric acid.

Properties. It has a sour, metallic taste, reddens the vegetable-blue colors, and combines with alkalies, forming arseniates. It is decomposed by hydrosulphuric acid. This acid is also an active poison.

Proto-chloride of arsenic, $AsCl$. 73.12, is prepared by heating in a retort, to nearly 212°, arsenious acid with ten times its weight of concentrated sulphuric acid, and throwing them in fragments of common salt.

Sesqui-chloride of arsenic, As^2Cl^3. 181.66, is formed by the spontaneous combustion of powdered arsenic in chlorine gas. It is a colorless, volatile liquid, giving off fumes, on exposure to the air; hence called *fuming liquor of arsenic*.

Periodide of arsenic, $2As+5I$. 706.9, is formed by gently heating arsenic with iodine. It is a deep red compound, decomposed by water.

Proto-hyduret of arsenic, $As+H$. 38.7, is prepared by the action of water on an alloy of arsenic and potassium.

Sesqui-bromide of arsenic. $2As+3Br$. 310.6. When arsenic and bromine are brought into contact, they instantly unite with vivid evolution of light and heat.

Arseniuretted hydrogen. $2As+3H$. 78.4. This gas was discovered by Scheele. It is generally made by digesting an alloy of tin and arsenic in hydrochloric acid. It is colorless, has a fetid odor resembling garlic, sp. gr. 2.695, extinguishes burning bodies, but burns with a blue flame. It is poisonous in a high degree, having proved fatal to M. Gehlen. It is decomposed by chlorine, iodine, caloric, and even atmospheric air; it forms with oxygen an explosive mixture.

Proto-sulphuret of arsenic. $As+S$. 53.8. This substance exists in the mineral kingdom, and is called *realgar*. It may be formed by heating arsenious acid with half its weight of sulphur, until the mixture is perfectly fused. It is crystalline, transparent, and of a ruby red color.

Sesqui-sulphuret of arsenic. $2As+3S$. 123.7. This in the native state is called *orpiment.*

Process. It may be formed by fusing arsenious acid and sulphur; but it is purer, if obtained by passing hydro-sulphuric acid gas through a solution of arsenious acid.

Properties. This substance has a rich, yellow color; and is employed as a pigment. It is the coloring principle in the paint called *king's yellow.*

Per-sulphuret of arsenic, $2As+5S$. 155.9, is formed by passing hydro-sulphuric acid through a moderately strong solution of arsenic acid. It resembles orpiment in color. The sulphurets of arsenic are poisonous.

CHROMIUM. Symb. Cr. Equiv. 28. Sp. gr. 5.9.

*Chromium** was discovered in 1797, by Vauquelin, in a beautiful red mineral, the native chromate of lead. It exists also in chromate of iron, a native mineral found abundantly in Europe, and also in this country.

Process. This metal has been obtained only in small quantities, owing to its affinity for oxygen. The oxide may be deprived of its oxygen, by heating it with charcoal in a smith's forge.

Properties. A brittle metal, of a greyish-white color, and very infusible. It is oxidized by heating it with nitre, and converted into chromic acid.

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* *Χρῶμα, color,* from its remarkable tendency to form colored compounds.

Compounds of Chromium.

Sesqui-oxide of chromium. $2Cr+3O$. 80. Exists native in the emerald.

Process. It is prepared by dissolving chromate of potassa in water, and mixing it with a solution of nitrate of mercury, when a yellow-colored precipitate, the chromate of mercury is formed. When this salt is heated to redness in an earthen crucible, the mercury is driven off, and the chromic acid is resolved into oxygen, and oxide of chromium.

Properties. Oxide of chromium is of a green color, very infusible, insoluble in water, and after being strongly heated, resists the action of the most powerful acids; heated with nitre, it is converted into chromic acid. Fused with borax or vitreous substances, it communicates to them a beautiful green color. Hence its utility in the arts. It unites with acids, and forms green-colored salts.

Chromic acid, $Cr+3O$. equiv. 52, may be obtained from the native *chromate of iron.*

Process. It is best prepared, by transmitting the gaseous fluoride of chromium into water contained in a vessel of silver or platinum; when by mutual decomposition of the gas and the water, hydrofluoric and chromic acids are generated.—T.

Properties. This acid is black while warm, and dark-red when cold. When dry, according to Hayes it is yellowish-brown, very soluble in water, rendering it red and yellow. When a heated concentrated solution cools, it deposits red crystals, very deliquescent. The solution has an acid, astringent taste, and bleaches litmus paper. It destroys most vegetable and animal coloring matters. Hence its use in calico-printing. It is characterized by its color, and by forming colored salts with alkaline bases.

Sesqui-chloride of chromium, $2Cr+3Cl$. 162.26, may be prepared by transmitting dry chlorine gas over a mixture of oxide of chromium and charcoal, heated to redness in a porcelain tube; when the sesqui-chloride gradually collects as a crystalline sublimate of a peach-purple color.—T.

Ter-chloride of chromium, $Cr+3Cl$. 134.26, is formed by the action of fuming sulphuric acid on a mixture of chromate of lead, and chloride of sodium.

Oxy-chloride of chromium. $CrCl^3+2CrO^3$. 238.26.

Sesqui-fluoride of chromium, $2Cr+3F$. 112.04, is formed by dissolving the oxide in hydrofluoric acid, and evaporating to dryness.

Ter-fluoride of chromium. $Cr+3F$. $28+56.04=84.04$.

Sesqui-sulphate of chromium, 2Cr+3S. 104.3, may be obtained by heating in close vessels a mixture of sulphur and the hydrated oxide. It is of a dark-grey color, acquiring a metallic lustre by friction.

Proto-phosphuret of chromium, Cr+P or CrP. 43.7, is prepared by passing phosphuretted hydrogen gas over the sesqui-chloride of chromium at a red heat; a black compound, burning before the blowpipe, with a flame of phosphorus.

VANADIUM. Symb. V. Equiv. 68.5.

Vanadium was discovered by Sefstrom in 1830. It derives its name from *Vanadis*, a Scandinavian Deity.

Natural History. It exists in the iron ore of Taberg, Sweden, and is found in great abundance in the slag formed by converting the cast-iron of Taberg, into malleable iron. It was also found by Johnson, at Wanlock-head, Scotland, where it occurs as a vanadiate of lead.

Process. It has been obtained in various ways—by heating vanadic acid with potassium, and by the decomposition of the chloride of vanadium.*

Properties. When obtained by means of potassium, it is a brittle, black substance; but when prepared by decomposing the chloride, it is white, resembling silver, of a strong metallic lustre. It is not oxidized by air or water; boiling sulphuric, hydrochloric, and hydrofluoric acids do not affect it, but it is dissolved by nitric and nitro-hydrochloric acids, and the solution has a fine, dark-blue color.

Compounds of Vanadium.

Protoxide of vanadium, V+O. 76.5, may be obtained by heating vanadic acid with charcoal, or hydrogen gas. It is a dark-brown, or black substance, soluble in nitric acid.

Binoxide of vanadium, V+2O. 84.5, may be prepared by heating to full redness 10 parts of the protoxide, with 12 of vanadic acid, in a vessel filled with carbonic acid. It is black, very infusible, and insoluble in water. Its salts have a blue color. It acts the part of an acid by uniting with alkaline bases.

Vanadic acid, V+3O. 92.5, is tasteless, insoluble in alcohol, and very slightly soluble in water. It is easily decomposed by heating it with combustible matter, and in solution by all deoxidizing agents. It unites with bases often in two or more proportions ; most of its neutral salts are yellow. It is distinguished from all other acids, except the chromic, by its color, and from this acid by the action of deoxidizing substances, which give a blue solution with the former, and green with the latter.*

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* For processes, see Turner's *Elements*.

MOLYBDENUM. Symb. Mo. Equiv. 47.7. Sp. gr. 8.615.

Molybdenum was discovered in 1775.

Process. It was obtained from the native sulphuret, by digesting it in nitro-hydrochloric acid, and heating the molybdic acid, thus formed in connection with charcoal.

Properties. It is a brittle metal, of a white color, and very infusible. Its properties are imperfectly known.

Protoxide of molybdenum, $Mo+O$. 55.7, is obtained by precipitating the hydrochloric solution of molybdic acid by zinc, when a brown hydrate is formed, giving dark-colored solutions with the acids.

Binoxide of molybdenum, $Mo+O$. 63.7, is prepared by putting a mixture of molybdate of soda and sal-ammoniac, in fine powder, in a red-hot crucible, instantly covering it, and continuing the heat until vapors of sal-ammoniac cease to arise. This is a deep brown anhydrous powder, insoluble in acids.

Molybdic acid, $Mo+3O$ or MO^3. 71.7, may be obtained by roasting the native sulphuret in an open crucible, kept at a low red heat, and stirred until sulphurous acid ceases to escape. The yellow powder thus formed is treated with ammonia; the filtered solution evaporated, again dissolved in water and ammonia, and crystallized; the ammonia is then expelled by gentle heat.

It is a white powder, sp. gr. 34.9 ; fuses at a red heat into a yellow liquid.† Slightly soluble in water.

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* The *bichloride of vanadium*, VCl^2. 68.5+70,34=139.34 ; the *terchloride of vanadium*, VCl^3. 68.5+106.26=174.76 ; the *bibromide of vanadium*, VBr^2. 68.5+156.8=225.3 ; the *bisulphuret of vanadium*, VS^2. 68.5+32.2=100.7 ; the *ter-sulphuret*, VS^3. 68.5+48.3=116.8, are unimportant compounds, for a description of which see Turner's Elements, p. 365.

† For the preparation of the *proto-chloride of molybdenum*, $MoCl$. 83.12 ; the *bichloride of molybdenum*, $MoCl^2$. 118.54 ; the *ter-chloride*

TUNGSTEN. Symb. W. Equiv. 94.8. Sp. gr. 17.5.

Tungsten, is found native in the mineral wolfram.

Process. It is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat.

Properties. It is a very hard, brittle metal, resembling iron in color, and by the action of heat and air converted into tungstic acid.

Compounds of Tungsten.

Binoxide of tungsten, $W+2O$. 110.8, is prepared by the action of hydrogen gas on tungstic acid, at a low red heat. It has a brown color, resembling copper when polished.

Tungstic acid, $W+3O$. 118.8, may be obtained by heating the binoxide to redness in open vessels. It is of a yellow color, insoluble in water, and has no action on litmus paper.

Bichloride of tungsten, $W+2Cl$. 165.64, is formed by heating tungsten in chlorine gas.*

COLUMBIUM. Symb. Ta. Equiv. 185.

Columbium was discovered in 1801, by Hatchett, in a black mineral in the British Museum, which had been sent by Gov. Winthrop to Sir Hans Sloane from Haddam in Connecticut.†

Process. It is obtained by heating potassium with the double fluoride of potassium and columbium.

Properties. Obtained in this way, it is a black powder, and a non-conductor of electricity, but a perfect conductor in a more dense state. It acquires a metallic lustre by pressure; of an iron-grey color, fuses at a higher temperature than

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of molybdenum, $MoCl^3$. 153.96; the *ter-sulphuret of molybdenum*, MoS^3. 96, and the *per-sulphuret of molybdenum*, MoS^4. 112.1, the student is referred to Turner's Elements, p. 369.

* For a description of the *ter-chloride of tungsten*, WCl^3. 201.6; *bisulphuret of tungsten*, WS^2. 126; and *ter-sulphuret of tungsten*, WS^3. 143.1, see Turner's Chemistry.

† Tantalum, discovered by Ekeberg, is identical with this metal

glass; heated in the open air, it takes fire, and is converted into columbic acid. It is easily dissolved in nitro-hydrofluoric acid.

Compounds of Columbium.

Binoxide of columbium, $Ta+2O$. 201, may be formed by exposing columbic acid in a crucible, lined with charcoal, and luted to exclude the air, for an hour and a half, to an intense heat. When reduced to powder, it is a dark brown substance, not acted upon by acids, but converted into columbic acid by fusion with potassa or nitre.

Columbic acid, $Ta+3O$. 209, is formed from the native columbates, by fusing the ores with three or four times their weight of carbonate of potassa, and precipitating the white hydrate by acids.

Properties. Hydrated columbic acid is tasteless, insoluble in water, and communicates a red tinge to moistened litmus paper; heated to redness the water is expelled, and the *anhydrous* columbic acid remains.*

ANTIMONY. Symb. Sb. Equiv. 64.6. Sp. gr. 6.702.

History. Antimony was discovered by Basil Valentine in the fifteenth century. It derived its name from *anti monk*, from its having proved fatal to some monks, to whom it was given as a medicine.

It is found native in Sweden, France, and the Hartz; but generally occurs as a *sulphuret.*

Process. It may be obtained by heating the native sulphuret in a covered crucible, with half its weight of iron filings, the sulphur unites with the iron, and the metal appears in the bottom of the crucible. Procured in this way, it is not absolutely pure, and for chemical purposes, it should be procured by heating the oxide with an equal weight of cream of tartar.

Properties. A brittle metal of a white color, fuses at

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* For a description of the *ter-chloride of columbium*, $Ta+3Cl$. 291.26; the *ter-fluoride of columbium*, $Ta+3F$. 241.04; and the *sulphuret of columbium*, composition uncertain, see Turner's Chemistry.

810°, and, on cooling, has a lamellated texture, and often yields crystals; burns with great brilliancy when placed on ignited charcoal, under a current of oxygen gas.

Compounds of Antimony.

Sesqui-oxide of antimony, $2Sb+3O$. 153.2, is obtained by subjecting antimony in a covered crucible to a white heat, and then exposing it to the air; a white vapor arises, and condenses in fine crystals of silver whiteness.

It is the only oxide which forms regular salts. It is the base of *emetic tartar*, and the tartrate of antimony and potassa. The test of antimony in solution is the hydrosulphuric acid, which yields an orange-colored precipitate.

Antimonious acid, $2Sb+4O$. 161.2, is generated when the oxide is exposed to heat in open vessels. It is white when cold, and yellowish when heated; very infusible and fixed in the fire, by which it is distinguished from the oxide; insoluble in water and in acids, after being heated to redness.

Antimonic acid, $2Sb+5O$. 169.2, may be obtained as a *white hydrate*, either by digesting the metal in strong nitric acid, or by dissolving it in nitro-hydrochloric acid, concentrating by heat to expel excess of acid, and throwing the solution into water.

It is decomposed at a red heat, and converted into antimonious acid.

Sesqui-chloride of antimony, $2Sb+3Cl$. 235.46, is generated by the spontaneous combustion of antimony in chlorine gas. It is a soft solid, called *butter* of antimony; easily fused, and deliquesces when exposed to the air.*

Sesqui-sulphuret of antimony, $2Sb+3S$. 177.5. This is the principal ore of the metal, and hence is generally employed in making the preparations of antimony. It is of an earthy appearance, but is sometimes found in acicular crystals, of a red-grey color and metallic lustre, sp. gr. 4.62. It may be formed artificially by fusing together antimony and sulphur.

Oxy-sulphuret of antimony is composed of 2 equiv. of $2Sb+3S$ and 1 equiv. of $2SbO^3=508.2$. This occurs native, the *red antimony* of mineralogists. *Glass*, *liver*, and *crocus* of antimony are of a similar nature.

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* *Bichloride of antimony*, $2Sb+4Cl$. 270.88; *perchloride of antimony*, $2Sb+5Cl$. 306.3; *oxy-chloride of antimony*, 2 equiv. of $2Sb+3Cl$. and 9 equiv. of $SbO^3=1849.72$; *bromide of antimony*, composition unknown.

Kermes mineral is formed by boiling the sesqui-sulphuret with a solution of potassa or soda On neutralizing the cold solution, a similar substance, the *golden sulphuret* is precipitated.*

Alloys. Printers' types are formed of three parts of lead, one of antimony, and a little copper.

Pewter is an alloy of twelve parts of tin, one of antimony, with a small addition of copper. The white metal for *teapots* is an alloy of one hundred parts of tin, eight of antimony, two of bismuth, and two of copper.

URANIUM. Symb. U. Equiv. 217. Sp. gr. 9.

Uranium was discovered by Klaproth in 1789. It derives its name from the planet discovered the same year, (Uranus). It exists in *pitch blende*, and is obtained from it by heating the ore to redness, and digesting its powder in pure nitric acid, diluted with three or four parts of water. Its properties are not well known.

Protoxide of uranium, $U+O$. 225, is obtained by decomposing the nitrate of the sesqui-oxide by heat. It is of a dark green color, very infusible, and readily oxidized by nitric acid; used in the arts to give a black color to porcelain.

Sesqui-oxide of uranium, $2U+3O$. 458, is of a yellow color, and combines with acids and alkaline bases.

The proto-chloride of uranium, $U+Cl$. 252.42; *the sesqui-chloride of uranium*, $2U+3Cl$. 540.26, and the *sulphuret of uranium*, are unimportant compounds. (See Turner, page 380.)

CERIUM.† Symb. Ce. Equiv. 46.

Cerium was obtained by Hisinger and Berzelius from a mineral called *cerite*. It exists also in the mineral called *Allanite*, as an oxide, which is very difficult to be reduced to the metallic state. Vanquelin obtained a small globule not larger than a pin's head, which was not acted upon by any of the simple acids, and but slowly dissolved by the nitro-hydrochloric.

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* *Bisulphuret of antimony*, $2Sb+4S$. 193.6; *per-sulphuret of antimony*, $2Sb+5S$. 209.7.

† So called from the planet Ceres, discovered about the same period.

Compounds of Cerium.

Protoxide of cerium, $Ce+O$. Eq. 54, is a white powder, insoluble in water. The salts which are soluble have an acid re-action.

Sesqui-oxide of cerium, $2Ce+3O$. 116, is obtained from *cerite*, and is a fawn-red substance, soluble in several of the acids.

Proto-chloride of cerium, $Ce+Cl$ or $CeCl$. $46+35.42=81.42$.

Sesqui-chloride of cerium, $2\ Ce+3Cl$ or Ce^2Cl^3. $92+106.26=198.26$.

Proto-sulphuret of cerium, $Ce+S$ or CeS. 62.1. (See Turner's Chemistry, p. 381.)

BISMUTH. Symb. Bi. Equiv. 71. Sp. gr. 9.822.

Native bismuth occurs in crystals, octohëdra, or cubes, containing arsenic and cobalt. It is also found combined with sulphur and oxygen, from which it is obtained by the aid of heat, and charcoal.

Properties. It is a brittle solid, generally composed of broad plates of a reddish-white color, very fusible; melts at 476° Far., and forms very fine crystals by slow cooling.

Exp. For this purpose, fuse a quantity of it in a crucible, and let it cool until a crust is formed; break the crust and pour out the fluid beneath, the inner surface will be lined with beautiful crystals. Under the compound blow-pipe it burns with much brilliancy, producing yellow fumes of protoxide.

Protoxide of bismuth, $Bi+O$. 79. Sp. gr. 8.211, may be formed as above. It forms salts, most of which are white; sublimes at a high temperature; fuses at a full, red heat, into a brown liquid. If the nitrate of the protoxide be thrown into water, a white precipitate is thrown down, formerly called *magistery of bismuth*, and *pearl white*, which is sometimes used as a paint, for *improving* the complexion.

Sesqui-oxide of bismuth, $2Bi+3O$. 166, is formed by fusing potassa with the protoxide of bismuth. It is a brown, heavy powder, little disposed to unite with acids, or alkalies.

Chloride of bismuth, $Bi+Cl$. 106.42, is formed by the spontaneous combustion of bismuth in chlorine gas, formerly called *butter of bismuth*. It is of a greyish-white color, and granular texture.

Bromide of bismuth, Bi+Br. 71+78.4=149.4.

Sulphuret of bismuth, Bi+S. 87.1, is found native.

TITANIUM. Symb. Ti. Equiv. 24.3. Sp. gr. 5.3.

Titanium was first noticed by Mr. Gregor of Cornwall. Klaproth gave it the name of titanium, after the Titans of ancient fable. But its properties were determined by Wollaston in 1822, who found it in the slag of an iron-smelting furnace in South Wales.

Properties. Its color is red, resembling copper. It exists in small cubes, which are so hard as to scratch rock-crystal, and very infusible. It generally contains traces of iron. The pure metal is obtained by heating the *chloride* with ammonia in a glass tube, when it appears in the form of a deep blue-colored powder, which is apt to take fire, if exposed to the air when warm.

Compounds of Titanium.

Oxide of titanium, Ti+O. 32.3, is obtained by exposing titanic acid to a strong heat in a black-lead crucible. It is of a purple color.

Titanic acid, Ti+2O. 40.3, also called *peroxide* of titanium, exists in the minerals *anatase* and *rutile*, from which the acid is obtained by the aid of heat and hydro-sulphuric acid gas.*

Properties. Titanic acid is of a white color; very infusible, and when once ignited, insoluble in acids, except in the hydrochloric. It is a feeble acid, resembling the silicic. If it is ignited with potassa, and dissolved in hydrochloric acid, a solution of gall-nuts will produce an orange-red color, which is very characteristic of titanic acid.

Bichloride of titanium, Ti+2Cl. 95.14, was discovered in 1824, by Mr. George of Leeds, by transmitting dry chlorine gas over titanium at a low, red heat.

Properties. A transparent, colorless liquid, which boils at 212°. The density of its vapor is 6.615, combines with water with explosive violence from the evolution of intense heat; on exposure to the atmosphere, it emits dense, white fumes, of a pungent odor, similar to chlorine.

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* For processes, see Turner's Elements.

Bisulphuret of titanium, $Ti+2S$. Eq. $24.3+32.2=56.5$.

TELLURIUM. Symb. Te. Equiv. 64.2. Sp. gr. 6.115.

Tellurium is a rare metal, found only in small quantities in Transylvania, and Connecticut. It was first noticed by Müller in 1782, but its existence was more fully established in 1798 by Klaproth, who called it *tellurium*, from *tellus*, the earth. It is found chiefly in combination with gold, and silver.

Properties. It is a brittle metal, of a bright grey color; very infusible and volatile. Heated in the air, it burns with a sky-blue flame, edged with green; placed upon charcoal before the blow-pipe, it inflames with violence, and flies entirely off in grey smoke, having a peculiarly nauseous smell.

Compounds of Tellurium.

Tellurous acid, $Te+2O$. 80.2, also called *oxide of tellurium*, is generated by the action of nitric acid on tellurium. It is a white, granular powder, resembling in many of its properties the titanic, and several other feeble acids. Its aqueous solution reddens litmus paper.

The other compounds are the *telluric acid*, $Te+3O$. 88.2; *chloride of tellurium*, $Te+Cl$. 99.62; *bichloride*, $Te+2Cl$. 135.04; *bisulphuret*, $Te+2S$. 96.4; *per-sulphuret* and *hydrotelluric acid*, $Te+H$. 65.2.

COPPER. Symb. Cu. Equiv. 31.6. Sp. gr. 8.895.

Copper, from *cuprum*, a name derived from the island Cyprus, has been known from the remotest ages.

Natural history. It is found native, and in combination with other substances, especially with sulphur. The copper of commerce is chiefly obtained from the native *sulphurets*. It exists in great abundance in Cornwall, and other parts of Europe, in Liberia, and in America.

Schoolcraft found a mass of native copper about thirty miles from Lake Superior, which weighs by estimation 2000 lbs.

Process. It may be obtained perfectly pure, by dissolving the copper of commerce in hydrochloric acid, diluting the solution, and immersing in it a clean plate of iron, upon which the copper will be precipitated.

Properties. Copper is distinguished from all other metals, except titanium, by its red color. It is very ductile, and malleable—melts at 1996° Far.; burns before the compound blowpipe with a beautiful, green flame, and if a fused globule be thrown into a glass jar, two feet high, filled with water, it will pass in full ignition to the bottom, and remain some time at a red heat.

Uses. Copper is one of the most useful metals, being employed extensively in most of the arts of life.

Compounds of Copper.

Red, or *dioxide of copper*, $2Cu+O$. 71.2, is found native in octohedral crystals.

It may be prepared artificially, by heating in a covered crucible, a mixture of 31.6 parts of copper filings with 39.6 of the black oxide.

Properties. It resembles copper in color, sp. gr. 6.093; soluble in ammonia, and the solution is colorless, but it absorbs oxygen on exposure to the air, which produces a blue color owing to the formation of the black oxide.

Black, or *protoxide of copper*. $Cu+O$. 39.6. This is the *copper-black* of mineralogists, and is formed by the spontaneous oxidation of other ores of copper.

Properties. It varies from a dark-brown to a blueish-black color, according to the mode of formation; combines with most of the acids, and its salts have a green, or blue tint. It forms with ammonia, a deep blue solution, which distinguishes it from all other substances. The salts of the protoxide of copper are mostly distinguished by their color. Metallic copper is separated from the salts by a rod of iron, or zinc.

Binoxide of copper, $Cu+2O$. $31.6+16=47.6$.

Dichloride of copper, $2Cu+Cl$. 98.62, is formed by the spontaneous combustion of copper filings in chlorine gas. It is of various colors, white, yellow, and dark-bown, according to the mode of preparation; soluble in hydrochloric acid, but not in water.

Chloride of copper, $Cu+Cl$. 67.02; *diniodide of copper*, $2Cu+I$. $63.2+126.3=189.5$; *sulphuret of copper*, $Cu+S$. 47.7, is a constituent of *copper pyrites*, in which it is combined with proto-sulphuret of iron; *triphosphuret of copper*, $3Cu+P$. 110.5; *subsequi-phosphuret*, $3Cu+2P$. 126.2; *cyanuret of copper*, $Cu+Cy$. 57.99; *Disulpho-cyanuret of copper*, $Cu+CyS^2$. $63.2+(26.39+32.2)=121.79$.—See Turner's Elements, p. 389.

Tests. The best mode of detecting copper in mixed liquids, is the hydro-sulphuric acid. The sulphuret, after being collected, and heated to redness in order to charr organic matter, should be placed on a piece of porcelain, and be digested in a few drops of nitric acid; sulphate of the protoxide of copper is formed, which, when evaporated to dryness, strikes the characteristic blue tint on the addition of ammonia.—T.

Alloys. The alloys of copper are very important and useful substances.

Brass is an alloy of copper and zinc. The best brass consists of four parts of copper to one of zinc. *Tutenag* contains in addition a little iron. *Tombac*, *Dutch-gold*, *Similor*, *Prince Rupert's metal* and *Pinch-beck* contain more copper than brass. *Bell-metal* and *bronze* are alloys of copper and tin. The best proportions for bell-metal, is three parts of copper to one of tin; for bronze, eight to twelve of tin to one hundred of copper. In these alloys, according to Dalton, the elements combine in definite proportions.

Poisonous properties of copper. Copper vessels used for culinary purposes, should be coated with tin, as the oxide is poisonous. This is done by making the surface of the copper bright, rubbing over a little sal-ammoniac to prevent oxidation, and then heating the vessel and rubbing it with rosin and tin.

LEAD. Symb. Pb. Equiv. 103.6. Sp. gr. 11.352.

Lead was well known to the ancients. It is rarely found native, but its ores are abundant, the most important of which is the sulphuret or *galena*, from which the pure metal is chiefly obtained.* Brezelius obtained the metal perfectly pure by heating the pure nitrate of lead, mixed with charcoal in a Hessian crucible.

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* *Process.* The ore, in the state of coarse powder, is heated in a reverberatory furnace, when part of it is oxidized, yielding sulphate of protoxide of lead, sulphuric acid which is evolved, and free oxide of lead. These oxidized portions then re-act on sulphuret of lead, by the re-action of two equivalents of oxide of lead, and one of the sulphu-

Properties. The properties of lead are generally well known. It is of a bluish-white color, soft, malleable and ductile. Fuses at 612°, and by slow cooling, crystallizes in octohedra. The proper solvent of lead is nitric acid.

Compounds of Lead.

Protoxide of lead, Pb+O. 111.6. sp. gr. 9.4214, is prepared by heating the metal to a high temperature and collecting the grey film which forms on the surface. This is exposed to heat in open vessels, until it acquires an uniform yellow color, and constitutes the *massicot*, and when partially fused, the *litharge* of commerce. This is always mixed with the red oxide; it is obtained perfectly pure by adding ammonia in excess, to the nitrate in solution, washing the precipitate in cold water, and when dry, heating it to redness for an hour in a platinum crucible.

Properties. Its color is red when hot, but acquires a rich lemon-yellow when cold; fuses at a bright red heat, and after fusion, has a highly foliated texture, insoluble in water, unites with acids and forms the base for all the salts of lead.

It is precipitated from its solutions by pure alkalies as a white *hydrate*, which is re-dissolved by potassa in excess; as a white *carbonate*, which is the well known *pigment* white *lead*, by alkaline carbonates; as a white sulphate, by soluble sulphates; as a dark-brown sulphuret by hydrosulphuric acid, and as a yellow iodide of lead by hydriodic acid, or iodide of potassium.—T.

Metallic lead is separated from the salts of the protoxide by iron or zinc.

Exp. In a solution of 1 part of acetate of lead in 24 parts of water contained in a glass bottle, suspend a piece of zinc

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ret, three equivalents of oxide of lead and one of sulphuric acid result, while one equivalent of the sulphuret, and one of the sulphate mutually decompose each other, giving rise to two equivalents of sulphurous acid, and two of metallic lead. The lead of commerce commonly contains silver, iron and copper.—T.

by a thread. The lead will be deposited upon the zinc in a form resembling a tree—a peculiar appearance called *arbor Saturni.*

Uses. Protoxide of lead enters into the composition of flint-glass, and is imployed for glazing earthen ware and porcelain.

Peroxide of lead, $Pb+2O$. 119.6, is formed by the action of nitric acid upon the red oxide, or *minium* of commerce. It is of a puce color, insoluble in water, and resolved by strong oxygen acids into a salt of the protoxide and oxygen gas.

Red oxide of lead, $3Pb+4O$. 342.8, is prepared by heating lead in the air nearly to the point of fusion, by which it is oxidized. It is then exposed to a temperature of 600° or 700°, while a current of air passes across its surface. It slowly absorbs oxygen, and is converted into the *minium* of commerce. It is employed as a pigment, and in the manufacture of flint-glass, but does not unite with acids and form salts.

Chloride of lead, $Pb+Cl$. 139.02, is obtained by adding hydrochloric acid to a solution of acetate or nitrate of lead. It is sometimes called *horn* lead ; dissolved in hot water, it appears on cooling in small acicular anhydrous crystals, of a white color.

Iodide of lead, $Pb+I$. 229.9 ; *bromide of lead,* $Pb+Br$. 182 ; *fluoride of lead,* $Pb+F$. 122.28 ; *sulphuret of lead,* $Pb+S$. 119.7 ; *phosphuret of lead* and *carburet of lead,* composition uncertain ; *cyanuret of lead,* $Pb+Cy$. 129.99.—(See Turner's Elements, p. 393.)

The salts of lead are generally poisonous, of which the carbonate is the most virulent.

Alloys of lead. Common pewter is an alloy of 20 parts of lead and 80 of tin. *Fine solder* consists of 1 part of lead and 2 of tin, and is employed for tinning copper. *Coarse solder* contains one fourth of tin and is used by plumbers. *Pot metal* is an alloy of lead and copper.

SECT. 6. METALS, THE OXIDES OF WHICH ARE REDUCED TO THE METALLIC STATE BY A RED HEAT.

MERCURY, or *QUICKSILVER.*

Symb. Hg. Equiv. 202. Sp. gr. 13.568.

Mercury was well known to the ancients. Its principal ore is the sulphuret or *native cinnabar,* from which it is separated by distillation with quick lime, or iron filings.

Properties. Mercury is the only metal which retains its liquid form at common temperatures. It is of a tin-white color, and strong metallic lustre; boils at 662° Far. and congeals at 40° below zero, in which state it is malleable, and has an increased specific gravity 15.612. It is not tarnished by exposure to cold moist air, unless it contain other metals. It is sometimes adulterated with an alloy of lead and bismuth, which renders it less fluid and volatile, leaving a residuum when boiled in a silver spoon.

Mercury is not acted upon by any of the acids except the sulphuric and nitric. It is used for collecting those gases which are absorbed by water.

Compounds of Mercury.

Protoxide of mercury, $Hg+O$. 210, is prepared by mixing *calomel* with pure potassa in excess in a mortar, and stirring it briskly to effect a rapid decomposition. The protoxide is then washed in cold water, and left to dry in a dark place.

Properties. It is a black powder, insoluble in water, combining with acids, and but feebly with alkalies. The alkalies precipitate it from the solution of its salts, as a black protoxide. The best test of its presence is the hydrosulphuric acid, by which it is thrown down as a black proto-sulphuret.

Binoxide of mercury, $Hg+2O$. 218, is commonly known by the name of *red precipitate*.*

Process. Peroxide of mercury may be prepared by dissolving mercury in nitric acid, and exposing the nitrate thus formed, to a temperature just sufficient to expel the whole of the nitric acid. It may also be formed by exposing mercury in a mattrass, with a long tube to the agency of heat and air, for the space of three or four weeks.

Properties. It exists in shining, crystalline scales, nearly black when hot, and red when cold; slightly soluble in water. The solution has an acrid, metallic taste, and is poisonous.

This oxide is separated from all acids by the carbonated fixed alkalies, and is reduced to the metallic state by copper.

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* This is the *hydrargyri oxidum rubrum* of the Pharmacop.

Proto-chloride of mercury, $Hg+Cl$. 237.42, is commonly called *calomel*, and was first mentioned in the seventeenth century by Crollius.

Process. It may be obtained by bringing chlorine gas in contact with mercury, but it is more commonly prepared by sublimation. This is done by mixing one equiv. of the bichloride with one equiv. of mercury, until the metallic globules entirely disappear, and then subliming. To purify it from corrosive sublimate, which is always mixed with it, when first prepared, it must be reduced to powder, and well washed, when it will be fitted for chemical, or medical purposes. The proto-chloride is also found native, and called *horn quicksilver*.

Properties. When obtained by this process, calomel exists in semi-transparent, crystalline cakes, of a yellow color when warm, but white when cold; sublimes a little below a red heat, and a part of it is resolved into mercury, and the bichloride. It is insoluble in water, and is decomposed by the pure alkalies.

Used extensively for medical purposes—acts powerfully upon the glandular system.

Bichloride of mercury, $Hg+2Cl$. 272.84, is formed by heating mercury in chlorine gas. During the process, the metal burns with a pale red flame. It is prepared for medical purposes by subliming a mixture of bisulphate of the peroxide of mercury with chloride of sodium, or sea salt.

Properties. Bichloride of mercury, commonly called ***corrosive sublimate***, is a most virulent poison. It is white, semi-transparent and crystalline in its texture; taste acrid and nauseous, more soluble in alcohol than in water, sp. gr. 5.2. It sublimes in the form of a dense, white vapor when heated, powerfully affecting the mouth and nose; soluble in hydrochloric, nitric and sulphuric acids, and is decomposed by the alkalies, and several of the metals.*

Tests. Place a drop of the suspected liquid on polished gold, and touch the moistened surface with the point of a pen-knife; the part touched will instantly become white, owing to the formation of an amalgam of gold.

Some animal and vegetable substances convert the bichloride into calomel; the best is albumen, made by mixing the white of an egg in water; hence the white of an egg is an antidote to poisoning by corrosive sublimate

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* *Protiodide of mercury*, $Hg+I$. 328.3; ***sesquiodide***, Hg^2I^3. 782.9; ***biniodide***, HgI^2. 454.6; ***proto-bromide***, $HgBr$. 280.4; ***bibromide of mercury***, $Hg+2Br$. 358.8; ***ioduretted bichloride of mercury***, $20HgCl^2+I$. 5583.1; ***iodobichloride of mercury***, $40HgCl^2+HgI^2$. 11368.2

Proto-sulphuret of mercury, $Hg+S$. 218.1.

Bisulphuret of mercury, $Hg+2S$. 234.2, may be formed by fusing sulphur with six times its weight of mercury, and subliming in close vessels.

Properties. When thus obtained, it has a red color, and is known by the name of *factitious cinnabar.* When reduced to powder its tint is greatly improved, and constitutes the well known pigment, *vermillion.* The native *cinnabar* is a *bisulphuret*, and is the principal ore of mercury.

Ethiops mineral is a mixture of sulphur and the bisulphuret, and may be formed by triturating equal parts of sulphur and mercury, until the globules of mercury disappear.

Bicyanuret of mercury, $Hg+2Cy$. 228.39, is prepared by boiling a solution of Prussian blue with an equal weight of peroxide of mercury in powder, until the blue color of the pigment entirely disappears. The solution on evaporation, yields quadrangular prisms of *bicyanuret of mercury;* it is colorless, inodorous, and highly poisonous.

Amalgams. Mercury combines with most of the metals, and forms a class of compounds called *amalgams.* An amalgam of one part of potassium and seventy of mercury is hard and brittle; on adding mercury to the liquid, alloy of potassium and sodium, solidification and combustion ensue; two parts of mercury, one of bismuth, and one of lead form a liquid amalgam, from which cubic crystals of bismuth are slowly formed. The combination of mercury with those metals which are not easily oxidized, enables them to combine with oxygen; hence gold and silver, in combination with mercury, are easily oxidized by heat and air. With tin it forms an amalgam for coating mirrors.

SILVER.[*] Symb. Ag. Equiv. 108. Sp. gr. 10.51.

Silver has been known from the earliest ages. It is found *native*, and in combination with other substances. The native silver occurs in octohedral or cubic crystals, seldom perfectly pure; it is generally found in primitive formations. Peru and Mexico contain the richest mines of native silver which are known.

Preparation. Pure silver may be obtained from standard silver, by dissolving it in nitric acid and introducing a clean piece of copper. The metal will be precipitated upon the copper; this is then to be washed in pure water, and digested in ammonia to remove the copper. A better process is to decompose the chloride of silver by carbonate of potassa.

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[*] Lat. *Argentum*.

Silver is often obtained from the argentiferous sulphuret of lead, by a process called *cupellation*.* Some of the ores are also reduced by amalgamation with mercury, and the mercury expelled by heat.

Properties. Silver has the clearest white color of all the metals. Its lustre when polished, is surpassed only by polished steel; so malleable, that it may be extended into leaves, less than a ten thousandth of an inch in thickness, and so ductile that it may be drawn into wire finer than the human hair; it fuses at 1873° Far. and appears extremely brilliant. It is not oxidized by air or moisture, but is tarnished by sulphurous vapors which act slowly upon it; it burns with a fine green light, and throws off fumes of oxide when exposed to the action of voltaic currents. None of the pure acids act upon it, but the sulphuric and nitric; the latter is its proper solvent, with which it forms the nitrate which, after fusion, is the *lunar caustic.*

Use. Silver is one of the precious metals, and is used as a coin and for various purposes of art.

Oxide of silver, $Ag+O$ or AgO. 116, is best formed by mixing a solution of pure baryta with the nitrate dissolved in water; it is of a brown color, insoluble in water, and easily reduced by a red heat.

Fulminating silver is a compound of oxide of silver and ammonia.

Process. Precipitate nitrate of silver by lime water, and after washing and drying the precipitate, put it into a vessel of pure ammonia for twelve hours; a black powder will be thrown down, which, when carefully dried, explodes violently by the gentlest heat, or by slight friction. Great care should be taken in its preparation, and it should be preserved in small quantities in paper boxes.

By heating the solution, a more dangerous compound is formed.

A compound similar to the above, but less dangerous, is formed by dissolving silver in nitric acid, and adding to the solution successive portions of alcohol. This substance is used in the preparation of small balls called *torpedoes*.

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* See Webster's Chemistry, 3d edit. p. 308.

Chloride of silver, $Ag+Cl$. **143.42**, is the ***horn silver*** of mineralogists.

It is formed by mixing hydrochloric acid with a solution of oxide of silver. When first precipitated it is white, but becomes almost black by exposure to the solar rays; insoluble in water, but very soluble in ammonia, by which it is usually distinguished from other chlorides. It is often employed in analysis as the means of ascertaining the amount of chlorine present in various compounds.

Iodide of silver $Ag+I$. 234.3, is a greenish-yellow substance.

Sulphuret of silver, $Ag+S$. 124.1. This is the *silver glance* of mineralogists. Silver has a strong affinity for sulphur; on passing a current of hydrosulphuric acid gas through a solution of lunar caustic, a dark brown precipitate subsides, which is a sulphuret of silver.

Cyanuret of silver, $Ag+Cy$. 134.39, is a white, curdy substance.

Alloys of silver. Silver is alloyed with most of the metals. With steel it forms an alloy used in cutlery; with copper it forms the silver plate and coin,* which is the most useful of its alloys; with mercury it forms an amalgam, sometimes employed for plating copper. Thermometer scales and clock dials, are usually silvered by an alloy of chloride of silver, chalk and pearlashes.

GOLD.† Symb. Au. Equiv. 199.2. Sp. gr. 19. 257.

Gold was known to the ancients, and has always been highly valued, as the most precious of the metals.

Natural History. Gold occurs *native* alloyed with a little silver or copper. It crystallizes in cubes and octohëdra; it is found in large quantities in alluvial soils, and in the beds of certain rivers, especially on the western coasts of Africa and Peru, in Brazil and Mexico, in Europe and the United States.‡

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* The standard silver of Great Britain contains $11\frac{2}{20}$ of pure silver, and $\frac{18}{20}$ of copper. That of the United States, one part by weight of copper, and nine of silver. The dollar weighs $412\frac{1}{2}$ grs. and the dime $41\frac{1}{4}$ grs.

† Lat. *Aurum.*

‡ The gold from all the mines in the United States in 1836, amounted to 467,000 dollars, 148,100 dollars of which were from North Carolina.

Process. Gold is generally separated by amalgamation, and cupellation, but the best mode is to fuse the gold with silver, so that the latter shall constitute $\frac{1}{4}$ of the mass; nitric acid will dissolve the silver, and leave the gold. This process is called *quartation.*

To obtain gold perfectly pure, dissolve standard gold in nitro-hydrochloric acid; evaporate the solution to dryness, re-dissolve it in distilled water, filter, and add to the solution sulphate of the protoxide of iron—a black powder falls, which, when washed in dilute hydrochloric acid, and distilled water, yields, on fusion, a button of pure gold.

Properties. Gold is distinguished from all other metals by its yellow color; it exceeds all others in ductility and malleability; it may be beaten into leaves not exceeding $\frac{1}{282000}$ of an inch in thickness; it is very flexible and soft; fuses at 2016° Daniell, and appears of a brilliant green color. It is not easily oxidized, even in the state of fusion, but on subjecting a fine wire to an electric discharge, a purple powder is produced which is probably an oxide; it is readily dissolved by nitro-hydrochloric acid.

Protoxide of gold, $Au+O$. 207.3, is formed by adding a cold solution of potassa to the proto-chloride, a precipitate falls of a green color, which changes spontaneously into metallic gold and teroxide.

Binoxide of gold, $Au+2O$. 215.2, is formed by the combustion of gold.

Teroxide of gold, $Au+3O$. 223.2, is the only well known oxide of gold.

Process. Dissolve one part of gold in the usual way, render it quite neutral by evaporation, and re-dissolve in twelve parts of water; to the solution add one part of the carbonate of potassa, dissolved in twice its weight of water, and digest at about 170°; carbonic acid gradually escapes, and the hydrated *teroxide*, of a brownish red color, subsides. After being well washed, it is dissolved in colorless nitric acid of sp. gr. 1.4, and the solution decomposed by admixture with water.

The hydrated teroxide is thus obtained quite pure, and is rendered anhydrous by a temperature of 212° Far.—T.

Properties. The hydrate is yellow, but the anhydrous teroxide is nearly black, insoluble in water, and completely decomposed by solar light, or a red heat. With alkalies it acts the part of a weak acid, and was called by Pelletier, *auric acid.* When the teroxide is kept in ammonia for the space of a day, a detonating compound of a deep olive color is formed. It is composed of one equiv. of gold, two of nitrogen, six of hydrogen, and three of oxygen.

The fulminating gold is a similar compound.

Process. Add pure liquid ammonia to the dilute chloride. The precipitate which is formed, will be re-dissolved if too much alkali is used; filter the liquid, and wash the sediment several times in warm water, dry it by exposure to the air, and preserve it in small paper boxes.

Exp. Hold, on the point of a knife, a small portion of the powder over the flame of a spirit lamp, and it will detonate violently.

Exp. Place two or three grains on a sheet of copper, and explode it, it will force a hole through the copper; a spark from the electrical machine, or from a flint will not affect it, but the slightest *friction* will cause it to explode, hence the danger of forming it, or of putting it up in large quantities.

Proto-chloride of gold, $Au+Cl$. 234.62.

Terchloride of gold, $Au+3Cl$. 305.46, is obtained, by concentrating a solution of gold, in ruby red crystals. This is the compound from which pure gold is obtained, and also most of the preparations of gold.

Exp. When a strong aqueous solution of the terchloride is shaken with an equal volume of ether, two fluids result, the lighter of which is an ethereal solution of gold.

Exp. When a piece of charcoal is immersed in the aqueous solution, and exposed to the solar rays, it is covered with metallic gold.

Exp. Ribbons are gilded by moistening them in this solution, and exposing them to a current of hydrogen gas.

Exp. Add the proto-chloride of tin to a dilute aqueous solution of gold, and a purple-colored precipitate, the *purple of Cassius,* is thrown down. On fusing this powder with sand and borax, it forms a purple enamel, which is used for giving a pink color to porcelain.*

Alloys of gold. Gold forms alloys with most of the metals. With tin it forms a whitish *brittle alloy.* On this account the old chemists called tin *diabolus metallorum.*

With lead, it forms a very brittle alloy. Even the fumes of lead destroy the ductility of gold. With copper it forms the alloy used for standard gold; which is perfectly malleable and ductile, harder than pure gold, and resists wear better than any other alloy, except that of silver, sp. gr. 17.157. The standard gold of the United States, is an alloy of 1 part of an alloy of copper and silver, and 9 parts of pure gold. The British "sovereign" is 22 carats fine, that is, 22 parts of pure gold, and 2 of copper and silver.

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* *Iodides of gold* are formed by the action of iodide of potassium on the terchloride of gold; *protiodide of gold*, $Au+I$. 325.5; *teriodide of gold*, $Au+3I$. 578.1; *tersulphuret of gold*, $Au+3S$. 247.5.

Water-gilding. Mercury and gold combine, and form an amalgam much employed in gilding. It is applied to the surface of silver, and the mercury driven off by heat.

Porcelain, is gilded with *gold powder*—obtained by decomposing the chloride of gold—applied with a pencil, and burnished after exposure to the heat of a porcelain furnace.

PLATINUM. Symb. Pl. Equiv. 98.8. Sp. gr. 21.25.

Platinum is a very rare metal. It occurs native in Brazil, Peru, and other countries of South America, in rounded or flattened grains, mingled with other metals. It is found in larger quantities in the Ural Mountains.

Properties. Platinum is the most dense of the metals, of a white color resembling silver. It is malleable, and so ductile, that it may be drawn into wire not exceeding $\frac{2}{1000}$ of an inch in diameter. It is soft, and easily welded, conducting caloric with less facility than many other metals. It is not attacked by any of the pure acids. Its solvent is chlorine, or nitro-hydrochloric acid. It is fused before the compound blow-pipe, and by voltaic electricity.

Spongy platinum,[*] has the remarkable property of causing oxygen and hydrogen gases to combine. Platinum-foil will produce similar effects. This is due to the attraction of the gases for the platinum, and the repulsive power of the gases themselves. They are thus so condensed upon the surface as to bring the particles of the gases within the sphere of each other's attraction.

Exp. Let a jet of hydrogen and oxygen upon a piece of spongy platinum—the gas will soon be inflamed.

Protoxide of platinum, $Pl+O$. 106.8, is prepared by digesting proto-chloride of platinum in a solution of pure potassa.

Binoxide of platinum, $Pl+2O$ or PlO^2. 114.8, is prepared with difficulty. According to Berzelius, it should be prepared by exactly decomposing sulphate of binoxide platinum with nitrate of baryta, and adding pure soda to the filtered solution, so as to precipitate about half of the oxide, which falls as a bulky hydrate of a yellowish brown color.

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[*] The sponge is prepared by adding ammonia to a solution of the chloride, and heating the precipitate to drive off the ammonia and chlorine.

Sesqui-oxide of platinum. $2Pl+3O$. 221.6. This oxide, of a grey color, is prepared by heating fulminating platinum with nitrous acid.

Proto-chloride of platinum, $Pl+Cl$. 134.22, is formed when the bichloride is heated to 450°; half of its chloride is expelled, and the proto-chloride, of a greenish-grey color, remains.

Bichloride of platinum. $Pl+2Cl$. 169.64. This chloride is obtained by evaporating the solution of platinum in nitro-hydrochloric acid to dryness, at a very gentle heat, when it remains as a red hydrate, which becomes brown when its water is expelled.—(See Turner, page 408.)

Protiodide of platinum, $Pl+I$. 225.1.

Biniodide of platinum, $Pl+2I$. 351.4, is prepared by the action of iodide of potassium on a rather dilute solution of bichloride of platinum. It is a black powder, tasteless, inodorous, and insoluble in water.

Proto-sulphuret of platinum, $Pl+S$. 114.9, is prepared by heating the ammoniacal chloride with half its weight of sulphur, until all the sal-ammoniac, and excess of sulphur are expelled.

Bisulphuret of platinum, $Pl+2S$. 131, is prepared by dropping a solution of bichloride of platinum into a solution of sulphuret of potassium.

Fulminating Platinum may be prepared by the action of ammonia in excess, on the sulphate of protoxide of platinum. It explodes at 420° with a very loud report, but does not explode by percussion.

Palladium, rhodium, osmium, and irridium are found associated with platinum, but exist in small quantities.

Palladium, Pd. 53.3. sp. gr. 11.5, was discovered by Wollaston, and resembles platinum in color and lustre.

Rhodium, R. 52.2. sp. gr. 11, was also discovered by Wollaston. It is, when fused, of a white color, hard, and extremely brittle. It attracts oxygen at a red heat, and a mixture of peroxide and protoxide of rhodium is formed, not acted upon by any of the acids, unless alloyed with other metals.

Osmium, Os. 99.7. sp. gr. 7 to 10, was discovered by Tennant in 1803. It is a black powder, which acquires metallic lustre by friction. When heated in the open air, it takes fire, and is readily oxidized and dissolved by fuming nitric acid.

Osmic acid, $Os+4O$. 137.7, is formed by the oxidation of osmium by acids, by combustion, or by fusion with nitre or alkalies. Its vapor is very acrid, exciting cough, irritating the eyes, and producing a copious flow of saliva.*

Irridium, Ir. 98.8. sp. gr. 15.3629, was discovered by Tennant in 1803, and about the same time by Descotils, of France. It is the most infusible of all metals, very brittle, and when polished resembles platinum.†

Latanium, is a metal recently discovered by Mosander. It is prepared by calcining the nitrate of cerium, mixed with nitrate of latanium.

CHAPTER V.

SALTS, OR SECONDARY COMPOUNDS.

Salts comprise a very extensive class of compounds, in which acids combine with oxides, or with other compounds having similar properties. The oxide which combines with the acid, is termed a *base*, or *salifiable base.*

The substances hitherto described are either simple bodies, or with a few exceptions, compounds of two simple elements, and are hence called *binary* compounds.

Salts, on the other hand, are composed of three or more simple bodies, and are hence termed *secondary* compounds. As salts, under favorable circumstances, readily assume regular crystalline forms, it seems proper, before proceeding to describe them, to present the subject of crystallization in general.

SECT. 1. CRYSTALLIZATION.

Most bodies, under favorable circumstances, may be made to assume the form of a regular geometrical solid. The process by which such a body is produced is called *crystalli-*

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* For other compounds of osmium, see Turner, 5th ed. p. 412.

† Irridium forms with oxygen four oxides, and with chlorine, four chlorides. (See Turner, 5th ed. p. 414.

zation; the solid is termed a *crystal;* and the science, the object of which is to study the form of crystals, is *crystallography.* The condition, by which this process is peculiarly favored, is the slow and gradual change of a fluid into a solid, the arrangement of the particles being at the same time undisturbed by motion. This is exemplified during the slow cooling of a fused mass of sulphur or bismuth, or the spontaneous evaporation of a saline solution. The numerous crystals found in the mineral kingdom, are due to the same cause.

The surfaces which limit the figure of crystals are called *planes* or *faces.* The lines formed by the junction of two planes are called *edges*, and the angle formed by two such edges is a *plane angle;* a *solid angle* is the point formed by the meeting of at least three planes.—T.

The *forms* of crystals are exceedingly diversified; they may be divided into *primary* and *secondary* forms.

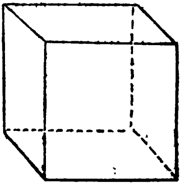
The *primary* forms are fourteen in number, and may be distributed as follows: 1. Prisms; 2. Octohedrons; 3. Dodecahedrons.

The prisms have either a *six-sided* base, or a *four-sided* base.

I. *Right Prisms.*

The bases are either right* or oblique, and the prisms are named according to their bases.

Fig. 70.



1. *The hexahedron* or *cube* (fig. 70.) is a figure bounded by six square faces, and all the angles of its edges are equal to 90 degrees.

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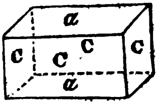
* The term *right* denotes, that the lateral and terminal planes are inclined to each other at a right angle. It is used in opposition to *oblique*, which signifies that the sides are not perpendicular, but form an oblique angle with the terminal planes.—T.

2. *The right square prism* (fig. 71.) differs from the cube in having its four lateral planes *cccc* rectangles, and the terminal planes *aa*, squares.

3. *The right rectangular prism*, (fig. 71.) differs from the former, in having the terminal planes *aa* rectangular instead of square.

Fig. 71.



4. *The right rhombic prism* (fig. 72.) differs from the two preceding only in its terminal planes being rhombs.

5. *The right rhomboidal prisms* (fig. 73.) differs from the preceding form in the terminal plans *aa* being rhomboids.

Fig. 72.

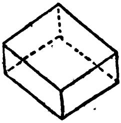
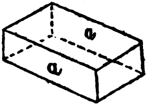


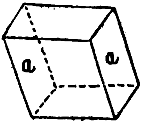
Fig. 73.



II. *Oblique Prisms.*

6. *The rhombohedron* (fig. 75.) is bounded by six rhombic faces, of the same size and form.

Fig. 74.



7. *The oblique rhombic prisms* (fig. 74.) have the terminal planes *ab* rhombs, with the lateral planes forming oblique angles with them.

8. *Oblique rectangular prism* differs from the preceding in having the terminal planes rectangles.

Fig. 75.

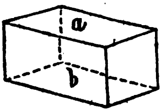
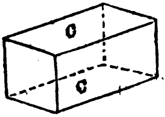


Fig. 76.



9. *Oblique rhomboidal prism* (fig. 76.) differs from the two preceding forms in the terminal planes *cc* being rhomboids.

The octohedrons are also named from their bases. The base of the octohedron is a section passing through four angles.

Fig. 77.

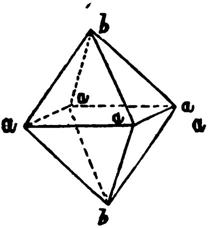
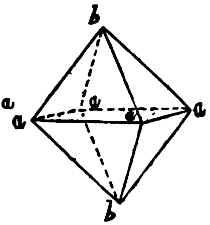


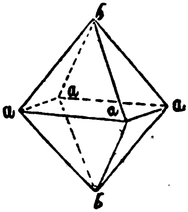
Fig. 78.



10. ***Regular octohedron*** (fig. 77.) has a square base *aaaa*, and is contained under eight equilateral triangles—hence all its plane angles are equal to 60 degrees. This figure is a ergular solid of Geometry.

11. ***Square octohedron*** (fig. 78.) has a square base *aaaa*, and is bounded by eight faces which are isoscles triangles. The base is always a square, the only part of the figure which is constant.

Fig. 79.



12. *Rectangular octohedron* (fig. 79.) has a rectangular base *aaaa*, and is bounded by eight isoscles triangles, four of which are different from the other four.

Fig. 80.

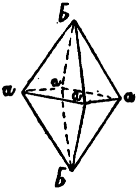
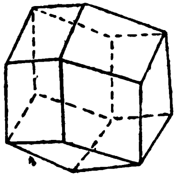


Fig. 81.



13. ***Rhombic octohedron*** (fig. 80.) has a rhombic base *aaaa*, and is contained under eight similar scalene triangles, but all its dimensions are variable.

14. ***Dodecahedron.***—There is but one primary dodecahedron, called the *rhombic dodecahedron*, (fig. 81.) and is limited by twelve similar rhombic faces; the faces incline to each other at an angle of 120 degrees.*

Secondary Forms.

The secondary forms of crystals are very numerous, amounting to millions; the forms of a single mineral *calcareous spar*, have been found to be nearly a thousand, but each of the secondary forms may be reduced to one or more of the primary, by a process called *cleavage;* this process is usually performed with a sharp instrument, by removing thin laminæ from the faces, edges or angles of the crystal. The surfaces exposed by splitting, or cleaving a crystal, are termed the *faces of cleavage,* and the direction in which it may be cleaved, is called the *direction of cleavage.* Some crystals are cleavable in one direction, and some in two, three, four, or more directions.

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* The instrument used for measuring the angles, at which the planes of crystals meet or incline to each other are called *goniometers.* See Dana's Mineralogy, p. 32, New Haven. 1837.

Those which cleave in more than two directions may, by the removal of layers parallel to the planes in their cleavage, be made to assume regular primary forms, whatever be their figure previous to cleavage.

It was formerly supposed, that each substance always had the same *primary* form, but the discovery was made by Mitscherlich in 1819, that *identity* of composition did not always indicate *identity* of crystalline form.

To this new branch of science the term *isomorphism* from ἴσος equal, and μορφὴ form,) is applied.*

The phenomena of crystallization is ascribed to cohesive attraction, or more properly to *crystallogenic attraction.*

The crystallization of salts is most readily effected by dissolving them in water, and evaporating the solution.

Exp. Introduce into a large matrass, a pound and a half of Glauber's salts (sulphate of soda), with a pound of water, and boil the mixture until all the salt is dissolved; cork it tight, as the heat is removed, and let it cool. On taking out the stopper, the salt will suddenly crystallize, and the whole will become nearly solid.

The water enters into the crystal in definite proportions, and is called the *water of crystallization.* The quantity of combined water is very variable in different crystals; such salts when heated, dissolve if soluble, in their own water of crystallization, undergoing what is termed *watery fusion;* some salts when exposed to the air, lose their water of crystallization, and crumble down into a fine powder. This is termed *efflorescence;* others absorb water from the atmosphere, and are said to *deliquesce.*

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* See Turner, 5th ed. p. 429.

Some salts enclose mechanically within their texture particles of water, by the expansion of which, when heated, they burst with a crackling noise; this is called *decrepitation.*

SECTION 2. ORDER 1.

Oxy-salts.

This order includes no compound, the acid or base of which does not contain oxygen. All the powerful alkaline bases, except ammonia, are protoxides of an electro-positive metal. If M represent an equivalent of any metal, $M+O$ or MO is the strongest alkaline base, and generally the only one which the metal is capable of forming; a single equiv. of acid neutralizes MO, forming a neutral salt. Thus, if an equiv. of sulphuric and nitric acids be represented by SO^3 and NO^5, all the neutral sulphates and nitrates of the protoxide will be indicated by $MO+SO^3$ and $MO+NO^5$; hence it may be inferred, that in each family of salts there is a constant ratio in the oxygen of the base, and that of the acid; that for sulphates is as one to three, and the nitrates as one to five. If the base be a binoxide, the same relation is preserved.

Those salts which are formed by the same acid, combined with different bases, have many properties in common, and hence they are classed in the same family.

Salts sometimes combine with each other, forming *double salts;* these are composed of two acids and one base, of two bases and one acid, or of two different acids and two different bases; these were formerly called *triple salts.*

Sulphates.

Many of the sulphates occur *native*, of which those of lime and baryta are the most abundant. They may all be formed by the action of sulphuric acid on the metals, their oxides, their carbonates, or by double decomposition. They vary in solubility in water, and are all decomposed at a white heat, and by carbonaceous matter with the aid of heat.

The acid of the sulphate is readily detected by the chloride of barium,—the acid having a stronger affinity for baryta than for any other alkaline base. The sulphates are a very numerous family of salts. The following are the most important.

Sulphate of potassa, $KO+SO^3$. 87.25, was formerly called *sal de duobus*, and *potassæ sulphas*. It may be prepared by neutralizing carbonate of potassa with sulphuric acid.

Properties. Taste saline and bitter. Its crystals belong to the *right prismatic system*, and contain no water; soluble in 16 times their weight of water at 60°, and in 5 of boiling water.

Bisulphate of potassa, $KO+2SO^3$. 127.35, with one equiv. of water 136.35. This salt is prepared by heating the sulphate, with half its weight of sulphuric acid, in a platinum crucible.

Properties. It has a sour taste, and reddens litmus paper; is more soluble than the sulphates, and its crystals belong to the same order. It is used for cleaning coin, and other works in metal.

Sulphate of soda, $NaO+SO^3$. 71.4, in crystals with 10 equiv. of water 161.4, is well known as *Glauber's salts.* It is found in the earth, and in the water of many springs. It is easily formed by saturating SO^3 with carbonate of soda.

Properties. Taste bitter, cooling and saline. Its crystals belong to the right prismatic system, effloresces on exposure to the air, and undergoes watery fusion when heated. 12 parts of the salt require 100 of water at 32° to dissolve them. *Used* in pharmacy, and in the manufacture of glass.

Bisulphate of soda, $NaO+2SO^3$. 111.5, with 4 equiv. of water 147.5.

Sulphate of litha, $LO+SO^3$. 58.1 in crystals with 1 equiv. of water 67.1, has a saline taste, very soluble and fusible, and crystallizes in flat prisms.

Sulphate of ammonia, H^3N+SO^3. 57.25, in crystals, with 1 equiv. of water 67.1, sometimes occurs native in volcanoes, and near certain small lakes in Tuscany. It may be prepared by neutralizing sulphuric acid with carbonate of ammonia. It is contained in soot from coal.

Properties. It crystallizes in long, flattened, six-sided prisms, soluble in two parts of water at 60°, and in an equal weight of boiling water; effloresces in warm, dry air, losing 1 equiv. of water; yields its water of crystallization by heat, fuses, and is decomposed, yielding nitrogen, water, and SO^3+H^3N.

Uses. It is the source of the *hydrochlorate of ammonia*, which is obtained by a mixture of common salt and sulphate of ammonia by sublimation.

Sulphate of baryta, $BaO+SO^3$. 116.8. sp. gr. 4.4, occurs *native* in great abundance, and is known by the name of *heavy-spar*.

Properties. Insoluble in water, and is precipitated by adding SO^3 to any soluble salt of baryta. So delicate is baryta as a test of SO^3, that 1 part of sulphate of soda in 400,000 of water is detected by it. It fuses at a high temperature into an opake, white enamel.

Uses. It is employed in the manufacture of *jasper ware*, and for a paint under the name of *permanent white.** (See Baryta, page 241, also Light, p. 63.)

Sulphate of strontia, $SrO+SO^3$. 91.9, occurs *native* in beautiful crystals in Sicily, and also on Strontian island, Lake Erie.

Properties. It has a blue tint and is called *celestine*; sometimes it is colorless and transparent, nearly insoluble requiring 4000 parts of cold, and 3840 of hot water to dissolve it. Heated with charcoal its acid is decomposed, and sulphuret of strontium is formed.

Sulphate of lime, $CaO+SO^3$. 68.6, with 2 equiv. of water 86.6, occurs in nature in large quantities. Every variety of *gypsum* is the sulphate combined with 2 equiv. of water, such as *Plaster of Paris, selenite*, which is a crystallized variety, *alabaster*, a white compact variety used in statuary, and *anhydrite*, which contains no water. The salt may be formed by mixing, in solution, a salt of lime with any soluble sulphate.

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* It is the best paint for marking phials and jars, in the Laboratory.

Properties. Crystals of ***anhydrite*** belong to the right, and of ***gypsum*** to the oblique prismatic systems. It is nearly tasteless, soluble in 500 parts of cold, and 450 of boiling water; hence it is generally found in spring and river water, and especially in those waters called ***hard.*** Baryta will detect the SO^3, and oxalic acid the lime. Heated to 212° ***in vacuo***, it parts with 1 equiv. of water, and at 300° the whole; in this state it is used as a cement. By mixing it with a certain portion of water it hardens rapidly, and becomes dry and solid; on this account it is much used for taking impressions, for stereotype plates, and for casts and busts.

Sulphate of magnesia, $MgO+SO^3HO$. 69.8, in crystals, with 6 equiv. of water=123.8, was procured from the springs of Epsom, England, and hence called ***Epsom salt.*** It is found native, and constitutes the ***bitter salt*** and ***hair salt*** of mineralogists. Sometimes it is found incrusting the damp walls of cellars and new buildings. Many saline springs contain it.

But it is generally obtained from sea-water, and exists in the bittern which is left after the crystallization of common salt. It is obtained by decomposing the hydrochlorate of magnesia contained in it with SO^3. It may also be formed from the carbonate by adding sulphuric acid.

Properties. It has a saline, bitter, and nauseous taste. Its crystals are small, quadrangular prisms,* slightly efflorescent in dry air, soluble in an equal weight of water at 60°, and ¾ of their weight of boiling water. They undergo watery fusion when heated, and are partially decomposed at a white heat.

Sulphate of alumina, $2AlO^3+SO^3$. 91.5; in crystals with 9 equiv. of water, 172.5.

Ter-sulphate of alumina, $2AlO^3+3SO^3$. 171.7; in crystals with 18 equiv. of water, 333.7

The hydrated disulphate is called ***aluminite.***

Sulphate of protoxide of manganese, $MnO+SO^3HO$. 84.8.

Sulphate of protoxide of iron, $FeO+SO^3HO$. 85.1; in crystals with five equiv. of water eq. 130.1. This is known by the name of ***green vitriol***, or ***copperas***. It is prepared on a large scale for the arts, by exposing the native proto-sulphuret of iron to air and moisture; the iron is converted into an oxide, and the sulphur into SO^3; they then combine and form the sulphate. It may also be formed by the action of SO^3 on the iron.

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* The larger crystals are generally right-rhombic prisms.

Properties. Its taste is strongly styptic and inky. When pure it does not redden the vegetable blue colors. Its crystals have a blue tint and belong to the oblique prismatic system; soluble in two parts of cold, and in $\frac{3}{4}$ its weight of boiling water. It is used in the manufacture of fuming sulphuric acid, and in dyeing.

Ter-sulphate of the sesqui-oxide, $2Fe^2O^3+SO^3$. 200.3.

Disulphate of the sesqui-oxide, $Fe^2O^3+3SO^3$. 200.1.

Sulphate of the protoxide of zinc, $ZnO+SO^3HO$. 89.4, with 6 equiv. of water=143.4, commonly called *white vitriol*, is formed by the action of dilute sulphuric acid on zinc. It is prepared in the arts by roasting the native sulphuret of zinc.

Properties. It crystallizes by spontaneous evaporation in transparent, flattened, four-sided prisms, referable to a right rhombic prism, and isomorphous with Epsom salt. Taste strongly styptic, and although a neutral salt, reddens vegetable blue colors; soluble in $2\frac{1}{2}$ parts of cold, and a less quantity of boiling water.

Use. A powerful emetic, and poisonous if given in large doses.

Sulphate of protoxide of nickel, $NiO+SO^3HO$. 86.6, crystallizes from its solution in pure water, in right rhombic prisms, and like most of the salts of nickel, is of a green color.

Sulphate of protoxide of cobalt, $CO+SO^3HO$. 86.6, is formed by digesting dilute SO^3 with oxide of cobalt. On evaporation it appears in the form of red crystals.

Ter-sulphate of the sesqui-oxide of chromium, $2CrO^2+3SO^3$. 200.3.

Sulphates of the oxide of Copper.

The *disulphate*, $2CuO+SO^3$. 119.3, has not been obtained in a separate state.

The *sulphate*, or *blue vitriol*, $CuO+SO^3HO$. 88.7, in crystals with 4 equiv. of water, 124.7, is formed by roasting the native sulphuret, or by dissolving the protoxide in dilute sulphuric acid, and crystallizing by evaporation.

Properties. The crystals are of a blue color and yield 4 equiv. of water at 212°, and the whole at 430° Far., when it becomes a white powder.

When ammonia is dropped into a solution of the sulphate it forms a dark blue solution, from which, when concentrated, crystals are deposited by the addition of alcohol. This is the *ammoniaret of copper* of the *U. S. Phar.*

Sulphate of the oxides of Mercury.

The *sulphate of protoxide*, $HgO+SO^3$. 250.1, is formed when two parts of mercury are heated with three of strong sulphuric acid so as to produce effervescence. If a strong heat is employed, the

Bisulphate, HgO^2+2SO^2. 298.2, results, both being anhydrous. When this bisulphate, the salt employed for making corrosive sublimate, is thrown into hot water, a yellow salt, the

Sub-sulphate, $4HgO^2+3SO^3$. 992.3, called *turpeth mineral*, is generated.

Sulphate of oxide of silver, $AgO+SO^3$. 156.1, is deposited when sulphate of soda is mixed with nitrate of silver, and also, by boiling silver with its weight of sulphuric acid.

Properties. It is white, and easily fused; soluble in 80 times its weight of hot water, and deposites small, needle-shaped crystals on cooling. It forms with ammonia a double salt, consisting of 1 equiv. of oxide of silver, one of acid, and two of ammonia. It crystallizes in rectangular prisms, isomorphous with the double chromate and seleniate of oxide of silver and ammonia.

Nitro-sulphuric acid, consisting of one part of nitric dissolved in ten of sulphuric acid, dissolves silver, but scarcely acts upon copper, lead or iron, unless diluted with water; hence its use in separating silver from old plated articles.

Double Sulphates.

Sulphate of soda and lime, $NaOSO^3+CaOSO^3$. 140, is the *Glauberite of mineralogists*, and occurs in the salt mines of New Castle.

Sulphate of potassa and magnesia, $KOSO^3+MgOSO^3$, is formed by mixing solutions of the two salts.

Sulphate of potassa and alumina, $KOSO^3+2AlO^33SO^3$. 258.95, do. with 24 equiv. of water=474.95. This salt, the *common alum*, is prepared by roasting and lixiviating certain clays, containing iron pyrites, and adding to the lyes a quantity of sulphate of potassa. It is obtained in Italy from *alum-stone*. Alum is also found in volcanic countries, produced by the action of sulphurous vapors on rocks containing feldspar.

Properties. It has a sweetish, astringent taste; is soluble in five parts of water at 60°, and crystallizes in octohedrons. Ignited with charcoal, it forms *Homberg's pyrophorous.*

Exp. Take 3 parts of lamp-black, 4 of calcined alum, and 8 of pearl-ashes; mix them thoroughly, and heat them in an iron tube to a bright cherry-red, for one hour; on removal from the fire, the tube must be carefully stopped. This substance, when exposed to the air and breathed upon, ignites with slight explosions. The essential part is probably *sulphuret of potassium* in minute divisions.

Use. Alum is of great use in the arts, especially in dyeing and calico-printing, because of its attraction for coloring matter.

Ammonia alum has the same form, appearance and taste.

Soda alum is also similar, except that it contains 26 equiv. of water.

Iron alum is formed by mixing sulphate of potassa with ter-sulphate of sesqui-oxide of iron; it resembles common alum in form, color, taste and composition.

Chrome alums. The ter-sulphate of sesqui-oxide of chromium forms double salts, with the sulphate of potassa and ammonia, very similar to the preceding.

Manganese alum is formed, by mixing a solution of ter-sulphate of sesqui-oxide of manganese with sulphate of potassa. These salts all crystallize in the octohedral system, and are similar in composition, one oxide being substituted for another, to form the different varieties.

Sulphites.

The salts of sulphurous acid have not hitherto been minutely examined; the sulphates of potassa, soda and ammonia, are made by neutralizing those alkalies with sulphurous acid, and are soluble in water; but most sulphates are sparingly soluble, if at all; they are decomposed by the stronger acids. See Turner, 5th edit. p. 443.

SECT. 3. NITRATES.

The nitrates may be prepared by the action of nitric acid on metals, on the salifiable bases, or on carbonates. As nitric acid forms *soluble* salts with all alkaline bases, the acids of the nitrates cannot be precipitated by any re-agent.—T.

The nitrates are all decomposed by a high temperature, and by the agency of heat and combustible matter, hence they are much employed as oxidizing agents. The process of oxidation by nitre, is called *deflagration*, which is generally performed by mixing the inflammable body with an equal weight of the nitrate, and projecting the mixture in small portions, into a red-hot crucible. All the neutral nitrates of the fixed alkalies and alkaline earths, together with most of the neutral nitrates of the common metals, are composed of one equiv. of nitric acid, and one of the protoxide, hence the oxygen of the base is to that of the acid, as one to five; the general formula is $MO+NO^5$.

Nitrate of potassa, $KO+NO^5$. 101.3, is an abundant natural product; it is obtained from the East Indies by lixiviating certain soils; in Germany and in France, it is produced in what are termed *nitre beds.*

The French process consists in lixiviating old plaster rubbish; it also exudes from new walls. Some caverns in Kentucky afford nitrate of lime, from which nitre is obtained by adding carbonate of potassa; it is also found under old buildings, and is commonly called *nitre* and *saltpetre*.

Properties. Colorless, has a saline and cooling taste, soluble in its own weight of boiling water; crystallizes in six-sided prisms without any water of crystallization, and fuses at 616°.

Fulminating powder is formed of three parts of nitre, two of dry sub-carbonate of potassa, and one of sulphur.

Exp. Heat a small quantity in the flame of a spirit lamp, and it will explode with considerable violence.

Uses. Used in chemistry as an oxidizing agent, and in the formation of nitric acid. In the East Indies it is employed for cooling mixtures; one ounce of nitre to five of water, reduces the temperature 15°. From its anti-septic properties, it is employed for preserving animal substances.

In the arts, it is extensively employed in the manufacture of gunpowder, which consists of nitre, sulphur and charcoal.

Nitrate of soda, $NaO+NO^5$. 85.45, called by the old writers *cubic nitre*, occurs in the soils of India, and in Peru; it is analogous in chemical properties to the preceding—mixed with charcoal, it burns more slowly than nitre.

Nitrate of ammonia, H^3N+NO^5. 71.3, is formed by neutralizing dilute nitric acid by carbonate of ammonia, and evaporating the solution. It is decomposed by heat, and yields the *exhilarating gas* or protoxide of nitrogen.

Nitrate of baryta, $BaO+NO^5$. 130.85, is easily prepared by digesting the native carbonate in nitric acid, diluted with eight or ten parts of water; on evaporation, crystallizes in transparent, anhydrous octohedrons; soluble in twelve parts of water at 60°, and three or four of boiling water. This salt is used as a re-agent—for preparing pure baryta, and in *pyrotechny*, to impart a green color to flame.*

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* The *green fire* is composed of 13 parts sulphur; 77 nitrate of baryta; 5 chlorate of potassa; 2 of arsenic, and 3 of charcoal.

Nitrate of strontia, $SrO+NO^5$. 105.95, in prisms with 5 equiv. of water=150.95, is prepared from the carbonate of strontia, in the same manner as the preceding, and has similar properties; it is used for the *red fire* employed at theatres.*

Nitrate of lime, $CaO+NO^5$. 82.65, is found in old plaster and mortar; very soluble and deliquescent; crystallizes in hydrated prisms.

The nitrate of magnesia, $MgO+NO^5$. 74.85 has similar properties.

Nitrate of protoxide of copper, $CuO+NO^5$. 93.75, is formed by the action of nitric acid on copper; its crystals are prisms containing 7 equiv. of water, of a deep blue color, soluble in water and alcohol, and deliquescent.

Exp. Spread a drachm of this salt on a piece of tin foil, moisten it with water, fold it, and lay it on a plate, sufficient heat will often be evolved to ignite the metal.

Nitrate of protoxide of lead, $PbO+NO^5$, 165.75, may be formed by digesting litharge in dilute nitric acid; it crystallizes in anhydrous octohedrons, and has an acid re-action.

Dinitrate of protoxide of lead, $2PbO+NO^5$. 223.2+54.15=277.35.

Nitrate of protoxide of mercury, $AgO+NO^5$. 264.15, in crystals with two equiv. water=282.15, is obtained by digesting mercury in nitric acid, diluted with three or four parts of water, until the acid is saturated, and then allowing the solution to evaporate spontaneously in an open vessel.

Nitrate of per-oxide of mercury, HgO^2+NO^5. 272.15, is formed by heating mercury with strong nitric acid in excess.

The solution on cooling, deposits transparent, prismatic crystals; when this salt is put into hot water, it is resolved into a soluble salt, whose composition is unknown, and into a yellow *dinitrate of the per-oxide*, HgO^2+NO^5, 490.15.

Nitrate of oxide of silver, $AgO+NO^5$. 170.15, may be formed by dissolving silver in nitric acid, diluted wtih three parts of water; if the silver contain copper, it will give a greenish hue to the solution; if it contain gold, it will appear in the form of a black powder. The solution should be perfectly clear and colorless.

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* *Red fire* consists of 40 parts of nitrate of strontia; 13 sulphur; 5 chlorate of potassa; and 4 sulphuret of antimony, with a little powdered charcoal.

Properties. The solution by evaporation, deposits transparent, tabular crystals; it is caustic, and tinges animal substances of a deep yellow, which becomes by exposure to light, deep purple or black, and is indelible.

Heated in a silver crucible to 426°, it fuses, and when cast into small cylinders, forms the *lunar caustic* of pharmacy. This when pure, is white and transparent, but the common lunar caustic is dark and opaque, owing to the decomposition of the nitrate, by raising the temperature too high in its preparation, and also, in consequence of copper and gold which are often contained in it; it is soluble in its own weight of cold, and in half its weight of boiling water.

It is decomposed by light, leaving a black stain upon the skin or on paper, (see p. 61.) hence it is a very delicate test of animal matter, also of chlorine and hydrochloric acid, which latter causes a white precipitate, the chloride of silver.

It is also decomposed by sulphur, phosphorus, charcoal, hydrogen, and several of the metals.

Exp. Place a few grains of this salt with a little sulphur, and also with phosphorus upon an anvil; when struck sharply with a hammer, the former will detonate, and the latter explode violently.

Exp. Dip a piece of silk into a solution of this salt, and while moist pass over it hydrogen gas, it will at first turn black, and then become irridescent from the reduction of the metal.

Exp. Immerse in a solution of this salt a stick of phosphorus, it will soon become beautifully incrusted with the metal.

Exp. Immerse a slip of ivory in a dilute solution of the salt, till the ivory has acquired a bright-yellow stain, remove it to a tumbler of distilled water, and expose it to the direct rays of the sun for two hours, when it will become black, but on rubbing it, the surface will become bright, resembling pure silver.

Nitrate of silver is the principal ingredient in *indelible ink,* and in those compounds which are used for changing the color of the hair.

In all these cases, the effect depends upon the reduction of a part of the silver to the metallic state.

Nitrites.

According to Turner, very little is known of these salts.

SEC. 4. CHLORATES.

The salts of chloric acid are very analogous to those of nitric acid. They are all soluble in water, and are distinguished by the action of strong hydrochloric and sulphuric acids, the former disengaging chlorine, and protoxide of chlorine, and the latter chlorous acid.

The chlorates are mostly composed of 1 equiv. of protoxide, and one of acid; hence the oxygen of the base is to that of the acid, as 1 to 5, or $Mo+ClO^5$.

None of the chlorates are found *native*, and those of baryta and potassa, are the only ones which require particular notice.

Chlorate of potassa, $KO+ClO^5$. 122.57, may be formed by transmitting chlorine gas through a concentrated solution of pure potassa, until the alkali is completely neutralized; the results are chloride of potassium, and chlorate of potassa.*

Properties. Chlorate of potassa generally occurs in 4 and 6 sided crystalline scales; colorless, and of a pearly lustre; soluble in 16 times its weight of water at 60°, and in 2½ of boiling water. It is anhydrous, and fuses at 400° or 500°, by increase of temperature, it yields pure oxygen gas.

It acts very energetically upon many inflammable bodies.

Exp. Put two grains of the salt into a mortar, with one grain of sulphur. Mix them accurately, and then strike the collected mass forcibly with the pestle; a loud detonation will ensue. Charcoal will produce a similar effect, or

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* For other processes, see Turner's Chemistry.

Exp. Instead of the sulphur, add a grain of phosphorus, and the detonation will be much louder.*

Many of the stronger acids decompose this salt.

Exp. Mix two parts of sugar, with one of chlorate of potassa, and pour upon it a few drops of sulphuric acid. The decomposition will be attended by a sudden inflammation.

Exp. Put two parts of this salt with one of phosphorus into a wine-glass filled with warm water, and then pour by means of the dropping-tube, strong sulphuric or nitric acids directly upon the salt, the phosphorus will ignite under the water, owing to the development of oxygen from the decomposition of the salt.

Uses. It is employed in the preparation of *percussion powder*, in which this salt is substituted for nitre.

Matches are also made by first dipping them in melted sulphur, and then in a composition of chlorate of potassa, sugar, gum arabic, and vermillion.

Lucifer matches have a similar composition.

An attempt was made in 1788 to substitute chlorate of potassa for nitre, in the manufacture of gunpowder; but as might have been expected, on triturating the mixture, it exploded with violence, and destroyed several of the operators.

A few grains of this salt, put into water with a few drops of hydrochloric acid, forms a convenient bleaching liquor.

Chlorate of baryta, $BaO+ClO^5$. 152.12, is prepared by digesting for a few minutes a concentrated solution of chlorate of potassa, with a slight excess of silicated hydrofluoric acid, the alkali is precipitated in the form of an insoluble, double hydrofluate of silica and potassa, while chloric acid remains in the solution. The liquid, after filteration, is neutralized by carbonate of baryta, which throws down the excess of silicated hydrofluoric acid, and chlorate of baryta remains in solution.

Properties. It yields, on evaporation, crystals in the form of 4 sided prisms, has a pungent taste, is soluble in 4 times its weight of cold, and in a smaller quantity of warm water. It is employed for forming chlorous acid.

Perchlorates.

The neutral proto-salts of perchloric acid, consist of one equiv. of acid and base, as is expressed by the formula,

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* The hands should be covered with gloves, and the mortar turned from the face.

$MO+ClO^7$. Most of the salts are deliquescent, very soluble in water, and soluble in alcohol. When heated to redness, they yield oxygen gas and metallic chlorides; and they are distinguished from the chlorates by not acquiring a yellow tint, on the addition of hydrochloric acid.—T.

The salts are formed by neutralizing the base with perchloric acid, excepting perchlorate of potassa, which is formed from the chlorate by heat and sulphuric acid.

Chlorites.

The alkaline chlorites are formed by transmitting a current of chlorous acid gas into a solution of the pure alkalies; they are remarkable for their bleaching and oxidizing properties.

Hypo-chlorites.

These salts may be formed by the action of chlorine gas on the alkaline bases; the most important of these, is the hypochlorate of lime, which is well known as a bleaching powder.

Iodates.

The salts of iodic acid are very similar in character to those of chloric acid; in all the neutral protiodates, the oxygen of the base and acid is in the ratio of one to five; the iodates are easily recognized by the action of de-oxidizing agents. Thus the sulphurous, phosphorous, hydrochloric and hydriodic acids, deprive the iodic acid in the salt of its oxygen, and set the iodine at liberty. None of the iodates are found native; they are all insoluble, or sparingly soluble in water, excepting the iodates of the alkalies.

Iodate of potassa, $KO+IO^5$. 213.45, may be obtained by adding iodine to a concentrated, hot solution of pure potassa, until the alkali is completely neutralized. All the insoluble iodates may be procured from this salt, thus the iodate of baryta may be formed, by mixing chloride of barium with a solution of iodate of potassa.

The bromates are very similar to the chlorates and iodates.

Phosphates.

There are three acids of phosphorus which are *isomeric*, the *phosphoric*, *pyro-phosphoric* and *meta-phosphoric;* hence it becomes necessary to have three corresponding families of salts.

1. *Phosphates.* All the neutral proto-phosphates are soluble in water, and redden litmus paper, on which account they are called *super-phosphates.*

The tri-phosphates, except those of the pure alkalies, are sparingly soluble, or insoluble in water, but are all dissolved by nitric or phosphoric acids. The phosphates and di-phosphates are changed by heat, into pyro-phosphates and meta-phosphates; the phosphates of the pure alkalies are but partially decomposed by heat and combustible matter, and those of baryta, strontia and lime, undergo no change, but most of the phosphates of the second class of metals are resolved into *phosphurets* by those agents.

The insoluble phosphates are decomposed when boiled with a strong solution of carbonate of potassa, or soda.

Tri-phosphate of potassa, $3KO+P^2O^5$. 212.85, is formed by adding caustic potassa in excess, to a solution of phosphoric acid.

Diphosphate of potassa, $2KO2HO+P^2O^5$. 165.7, is prepared by neutralizing the super-phosphate of lime obtained from bones, with carbonate of potassa.

Phosphate of potassa, $KO2HO+P^2O^5$. 136.55, is formed by adding phosphoric acid to carbonate of potassa, until the liquid ceases to give a precipitate with chloride of barium, and then setting aside to crystallize.

Tri-phosphate of soda, $3NaO+P^2O^5$. 165.3, in crystals, with 24 equiv. of water=381.3. This salt is prepared by adding pure soda to a solution of the succeeding compound, until the liquid feels soapy to the fingers; the solution is then evaporated until a pellicle forms; on cooling, the crystals which are deposited, are quickly re-dissolved in water, and are crystallized.

Properties. Triphosphate of soda crystallizes in colorless, six-sided, slender prisms, which have an alkaline taste and reaction; soluble in five times their weight of water at 60°, and in still less of hot water; the crystals undergo watery fusion at 170°, but are not decomposed at a red heat. The feeblest acid deprives the salt of $\frac{1}{3}$ of its soda.

Triphosphate of soda and basic water, $2NaOHO+P^2O^5$. 143, in crystals with 24 equiv. of water=359. This salt is the most common of the phosphates, being manufactured on a large scale, by neutralizing with carbonate of soda, the acid phosphate of lime, which is procured by the action of sulphuric acid on burned bones.

Properties. It crystallizes in oblique rhombic prisms; hence called *rhombic phosphate;* its crystals are always alkaline to test paper, effloresce in the air; soluble in four times their weight of cold, and twice their weight of warm water.

Acid triphosphate of soda and basic water, $NaO.2HO+P^2O^5$. 120.7, in crystals with 2 eq. water=138.7, is commonly called the *biphosphate of soda*, and may be formed by adding phosphoric acid to a solution of carbonate of soda, until it ceases to give a precipitate with chloride of barium. When the solution is concentrated, it yields two different kinds of crystals without varying its composition.

Phosphate of soda and ammonia, $NaO.H^3N+P^2O^5$. 119.85, with 10 eq. water=209.85, is easily prepared by mixing 1 eq. of hydrochlorate of ammonia, and 2 equiv. of the rhombic phosphate of soda; each being previously dissolved in a small quantity of boiling water.

It is known as *microcosmic salt*, and is much employed as a flux in experiments with the blow-pipe; when heated, it parts with its water and ammonia.

Diphosphate of ammonia, $2H^3N+P^2O^5$. 105.7, in crystals with 3 equiv. water=132.7, is prepared by adding ammonia to phosphoric acid until a precipitate is formed; the primary form of the crystals is an oblique rhombic prism.

Phosphate of ammonia, $H^3N+P^2O^5$. 88.55, in crystals with 3 equiv. water=115.55, is formed in the same manner as the phosphate of potassa, crystallizes in octohedrons with a square base, and in right square prisms.

Bone phosphate of lime, $8CaO+3P^2O^5.442.2$, exists in bones after calcination, and fall as a gelatinous precipitate, on pouring chloride of calcium into a solution of rhombic phosphate of soda.

Triphosphate of lime, $3CaO+P^2O^5$. 156.9, occurs in the mineral called *apatite*.

Diphosphate of lime, $2CaO+P^2O^5+1$ eq. basic water, $= 137.4$, commonly called *neutral phosphate*, falls as a granular precipitate, when the rhombic phosphate of soda is added drop by drop, to chloride of calcium in excess.

Phosphate of lime, $CaO+P^2O^5+2$ eq. basic water, $=117.9$, is commonly called the *biphosphate* from its acid re-action, and may be formed by dissolving either of the preceding salts in a slight excess of phosphoric acid; it exists in urine.

Diphosphate of magnesia, $2MgO+P^2O^5$. 112.8.

Triphosphate of magnesia, $3MgO+P^2O^5$. 133.5.

Phosphate of ammonia and magnesia, $2MgO+2H^3N+10HO+P^2O^5$. 237.1, subsides as a pulverulent, granular precipitate from neutral alkaline solutions, containing phosphoric acid, ammonia and magnesia; it constitutes a variety of urinary concretions.

Triphosphate of oxide of silver, is formed when the rhombic phosphate of soda is mixed in solution with nitrate of silver; it is a yellow powder when dry, on exposure to light, it is speedily blackened.

Pyrophosphates.

The only salts of this family which have been studied, are those of soda and oxide of silver.

They are thus constituted.

Dipyrophosphate of soda, $2NaO+P^2O^5$. $62.6+71.4=134$.

Dipyrophosphate in crystals, with 10 eq. water, $90=224$.

Acid dipyrophosphate of soda and basic water, $NaO.HO+P^2O^5= 111.7$.

Pyrophosphate of soda, $NaO.P^2O^5$. $31.3+71.4=102.7$.

Dipyrophosphate of oxide of silver, $2AgO+P^2O^5$. $232+71.4=303.4$.

Metaphosphates.

The only salts of this family yet examined, are those of soda, baryta, and oxide of silver.

Metaphosphate of soda, $NaO.P^2O^5$. 1 eq. Na. 31.5+1 eq. P^2O^5. 71.4=102.7.

Metaphosphate of baryta, $BaO.P^2O^5$, 1 eq. BaO. 767+1 eq. P^2O^5. 71.4=148.1

Metaphosphate of silver, $AgO.P^2O^5$. 1 eq. AgO. 116+1 eq. P^2O^5. 71.4=187.4.

Sub-metaphosphate of silver, $3AgO+2P^2O^5$. 3 eq. AgO. 348+2 eq. P^2O^5. 142.8=490.8.

Arseniates.

Arsenic acid resembles the phosphoric in composition, and in many of its properties. The oxygen of the oxide and acid in their salts is as one to five; salts of two equiv. of basic water are soluble in water, redden litmus paper, and are usually considered *bisalts;* those with one equiv. of basic water, in which the oxygen of the base and acid is as two to five, are commonly called *neutral arseniates;* those without water are described as *sub-arseniates.* This acid has a strong tendency to form *tri-salts;* some of the arseniates bear a red heat without decomposition, but all are decomposed when thus heated with charcoal, metallic arsenic being set at liberty.

The *soluble arseniates* are easily recognized by the tests for arsenic, (see p. 243)

The *insoluble arseniates* are tested, by boiling them in a strong solution of the fixed alkaline carbonates, by which they are deprived of their acid; the acid may then be detected in the usual way.

The following are the principal arseniates:

Triarseniate of soda, $3NaO+As^2O^5$. 3 eq. NaO. 93.7+1 eq. As^2O^5. 115.4=209.3.

Do. in crystals with 24 eq. water 216=425.3.

Diarseniate of soda and basic water, $2NaO+HO+As^2O^5$. eq. 187.

Acid arseniate of soda and basic water, $NaO+2HO+As^2O^5aq.$= 164.7.

Triarseniate of potassa, $3KO+As^2O^5$. 3 eq. KO. 141.45+1eq. As^2O^5. 115.4=256.85.

Diarseniate of potassa, $2KO+As^2O^5$. 2 eq. KO. 94.3+1 eq. As^2O^5. 115.4=209.7.

Arseniate of potassa, $KO.As^2O^5$. 1 eq. KO. 47.15+1 eq. As^2O^5. 115·4=162.55.

Diarseniate of ammonia, $2H^3N+As^2O^5$. 2 eq. NH^3. 34.3+1 eq. As^2O^5. 115.4=149.7.

Arseniate of ammonia, $NH^3.As^2O^5$. 1 eq. NH^3. 17.55+1 eq. As^2O^5. 115.4=132.55.

Triarseniate of baryta, $3BaO+As^2O^5$. 3 eq. BaO. 230.1—1 eq. As^2O^5. 115.4=345.5.

Diarseniate of baryta, $2BaO+As^2O^5$. 2 eq. BaO. 153.4+1 eq. As^2O^5. 115.4=268.8.

Arseniate of baryta $BaO+As^2O^5$. 1 eq. BaO. 76.7+1 eq. As^2O^5 115. 4=192.1.

Triarseniate of lime, $3CaO+As^2O^5$. 3 eq. CaO. 85.5+1 eq. As^2O^5. 115.4=200.9.

Diarseniate of lime, $2CaO+As^2O^5$. 2 eq. CaO. 57+1 eq. As^2O^5 115. 4=172.4.

Arseniate of lime, $CaO+As^2O^5$. 1 eq. CaO. 28.5+1 eq. As^2O^5 115. 4=143.9.

Triarseniate of lead, $3PbO+As^2O^5$. 3 eq. PbO. 334.8+1 eq. As^2O^5. 115.4=450.2.

Diarseniate of lead, $2PbO+As^2O^5$. 2 eq. PbO. 223.2+1eq. As^2O^5. 115·4=338.6.

Triarseniate of ox-silver, $2AgO+As^2O^5$. 3eq. AgO. 348+1 eq. As^2O^5. 115.4=463.4.

Arsenites.

The arsenites of potassa, soda, and ammonia may be prepared by acting with those alkalies on arsenious acid.

They are very soluble in water, and have an acid re-action.

Most of the other arsenites are insoluble or sparingly soluble in water, but are dissolved by an excess of arsenious, nitric, and most other acids, with which their bases do not form insoluble compounds.

They are all decomposed when heated in close vessels.

The soluble salts, if neutral, are characterized by forming a yellow arseniate of oxide of silver, when mixed with nitrate of silver, and a green arsenite of protoxide of copper, *Scheele's green* with sulphate of copper.

The arsenite of potassa is the active principle in *Fowler's arsenical solution.*

Chromates.

The chromates may generally be known by their yellow, or red color. They may be known chemically by the green solution of chloride of chromium, formed by boiling any chromate with hyhrochloric acid mixed with alcohol. They are all decomposed by heat and combustible matter.

Chromate of potassa, $KO+CrO^3$. 99.15, is formed by heating to redness the native oxide of chromium and iron, (*chromate of iron*,) with nitrate of potassa, when chromic acid is generated, and unites with the alkali of the nitre.

Properties. Taste cool, bitter, and disagreeable, soluble in boiling water, and insoluble in alcohol.

Bichromate of potassa, $KO+2CrO^3$. 151.15, is of great importance in dyeing. It is prepared by acidulating the neutral chromate with sulphuric, or still better, with acetic acid, and allowing the solution to crystallize by spontaneous evaporation.

Properties. When slowly formed, 4 sided rhombic prisms are deposited, which are anhydrous, and of a rich, red color; soluble in 10 times their weight of water at 60°, and the solution reddens litmus.

The insoluble chromates, such as those of baryta, zinc, lead, mercury and silver, are prepared by mixing the soluble salts of those bases, with a solution of chromate of potassa.

Chromate of lead. $PbO+CrO^3$. 163.6. This is the yellow chromate, and is extensively used as a pigment. *Chromate of oxide of zinc*, may be used for the same purpose.

Borates.

The boracic is a feeble acid, and neutralizes imperfectly; hence the borates, such as soda, potassa and ammonia, have an alkaline reaction; hence also, the more powerful acids separate the alkali from boracic acid, although at a red heat boracic acid, owing to its fixed nature, decomposes *every salt* whose acid is volatile. The borates of the alkalies are soluble in water, but most of the other borates are sparingly soluble; they are not decomposed by heat, though remarkable for their fusibility. They are distinguished by the following character.

By digesting any borate in an excess of strong sulphuric acid, evaporating to dryness, and boiling the residue in strong alcohol, the solution will burn with a *green flame.*

Biborate of soda, $2BO^3+NaO$. 191.1, in crystals with 10 equiv. of water=101.01, commonly called *borax*, occurs native in certain lakes in Thibet. It is imported from India under the name of *tincal*, which after purification constitutes the *refined borax* of commerce.

Properties. It crystallizes in hexahedral prisms. The crystals are efflorescent; when heated they lose their water of crystallization, fuse and form on cooling a crystalline mass called *glass of borax.*

Borax is much used as a flux for welding iron and steel.

Boracite is a biborate of magnesia.

A new biborate of soda has been lately described, better as a flux for the use of jewellers than the preceding.

Carbonates.

The carbonates are distinguished from all other salts, by being decomposed with effervescence, owing to the escape of carbonic acid gas, by nearly all acids.

All the carbonates, except those of potassa, soda and lithia, are decomposed by heat; and all except those of potassa, soda and ammonia, are of sparing solubility in pure water; but all are soluble in excess of carbonic acid. Several of them occur native.

Carbonate of potassa, $KO+CO^2$. 69.27, is procured by lixiviating the ashes of land plants, and boiling the lye — a process, which is performed on a large scale in Russia, and in this country. This is the impure carbonate of commerce, known by the names *potash* and *pearlash*, and is of great utility in the arts, especially in the manufacture of soap and glass. As thus prepared, it always contains other compounds, such as sulphate of potassa, and chloride of potassium. For chemical purposes, it is obtained by heating cream of tartar to redness, when the acid is decomposed, and a pure carbonate of potassa mixed with charcoal remains. The charcoal is removed by solution in water, and evaporation.

Properties. Taste strongly alkaline, and slightly caustic; changes the vegetable purple colors to green; soluble in less than an equal weight of water at 60°; deliquesces on exposure to the air; is insoluble in pure alcohol, and fuses at a full red heat, but undergoes no other change.

Bicarbonate of potassa, $KO+2CO^2$. 91.39, in crystals with one equiv. water=100.39, is made by transmitting a current of carbonic acid gas through a solution of the carbonate. This salt is milder than the carbonate, into which it is converted by a low red heat. It does not dedeliquesce on exposure, and requires 4 times its weight of water at 60° for solution.

Carbonate of soda, $NaO+CO^2$. 53.42, in crystals with 10 equiv. water=143.42, is obtained from the ashes of sea-weeds, in the same manner as carbonate of potassa. The best variety of the impure salt is the *barilla*, which consists of the semi-fused ash of the *salsola soda*, a plant cultivated on the Mediterranean shores of Spain. *Kelp* is another variety, and formed from the sea-weeds on the northern shores of Scotland.

Properties. Crystallizes in rhombic prisms, effloresces, and dissolves in its water of crystallization when heated, and becomes anhydrous by continued heat; soluble in about 2 parts of cold, and in less than its weight of boiling water.

Bicarbonate of soda, $NaO+2CO^2$, 75.54, in crystals with one equiv. water=84.54, is formed by the same process as the bicarbonate of potassa, and like that salt, is much milder than the carbonate.

Sesqui-carbonate of soda, $2NaO+3CO^2$. 4HO. 164.96, is found *native* in Africa on the banks of soda lakes, and is called *Trona*.

Carbonate of ammonia, H^3N+CO^2. 39.27, is obtained by mixing dry carbonic acid over mercury, with twice its vol. of ammoniacal gas; it is a dry, white powder, and has an alkaline re-action; its odor is pungent, resembling ammonia.

Bicarbonate of ammonia, $H^3N.2HO+2CO^2$. 79.39, is obtained by transmitting a current of carbonic acid gas, through a solution of carbonate of ammonia, and evaporating the solution by gentle heat; it is deposited in right rhombic prisms, inodorous and nearly tasteless.

Sesqui-carbonate of ammonia, $2H^3N.2HO^2+3CO^2$. 118.66, is prepared by heating one part of hydrochlorate of ammonia, mixed with one and a half of carbonate of lime carefully dried.

The *chloride of calcium* remains in the retort, and this salt is sublimed; it is hard, compact, translucent, of a crystalline texture, and ammoniacál odor.

Carbonate of baryta, $BaO+CO^2$. 98.82, occurs native in the mineral *Witherite;* it may be prepared by mixing a soluble salt of baryta, with any of the alkaline carbonates.

Properties. This salt is anhydrous, very insoluble, and highly poisonous.

Carbonate of strontia, $SrO+CO^2$. 73.92, is known by the name of *strontianite;* it may be prepared in the same manner as carbonante of baryta; it is soluble in excess of carbonic acid.

Carbonate of lime, $Ca+CO^2$. 50.62, is a very abundant natural production, occurring under a great variety of forms, such as lime-stone, marble, chalk, Iceland spar, etc. often in regular crystals. Carbonic acid and lime have a strong affinity for each other, and hence moist lime, or lime in solution, when exposed to the air, absorbs the acid contained in the atmosphere, and carbonate of lime is formed. It is sparingly soluble in water, but soluble in excess of carbonic acid; the crust formed on the top of lime water, is carbonate of lime.

Carbonate of magnesia, $MgO+CO^2$. 42.82, in crystals with 3 eq. water=69.82, is found native in the mineral called *magnesite*, which is nearly pure, anhydrous carbonate of magnesia; it is obtained in minute, transparent, hexagonal prisms, when a solution of the *bicarbonate* evaporates slowly in an open vessel; the crystals lose their water, and become opake by a very gentle heat, and even in dry air at 60°. They are decomposed by water.

A *carbonate of magnesia*, consisting of four equiv. of water, three of acid, and four of magnesia, falls as a white powder when carbonate of potassa is added to a hot solution of sulphate of magnesia; this salt is very insoluble, requiring 9000 parts of hot water for solution.

Carbonate of protoxide of iron, $FeO+CO^2$. 58.12, is a very abundant, natural production, occurring either in masses, or in rhombohedrons. It exists also in most of the chalybeate mineral waters. It may be formed by mixing an alkaline carbonate with sulphate of protoxide of iron. It acts as a tonic upon the animal system.

Dicarbonate of protoxide of copper, $2CuO+CO^2$. 101.32, is found native as a hydrate, in the mineral called *malachite*, of a beautiful green color.

It may be obtained by precipitation from a hot solution of sulphate of protoxide of copper, by carbonate of soda or potassa; this is the *mineral green* of painters.

When the hydrate is boiled for a long time in water, it loses both carbonic acid and combined water, and the color changes to a brown.

The *blue copper ore* and the blue pigment called *verditer*, have a similar composition.

Carbonate of protoxide of lead, $PbO+CO^2$. 133.72, is the *white lead* of painters. It occurs native in white prismatic crystals. As an article of commerce, it is prepared from the sub-acetate by a current of carbonic acid; also by exposing metallic lead in minute division to air and moisture, or by the action of the vapor of vinegar on thin sheets of lead.

Dicarbonate of peroxide of mercury, $2HgO^2+CO^2$. 458.12. When a solution of the nitrate of peroxide of mercury, is decomposed by carbonate of soda, this salt falls as an ochre-yellow precipitate.

Double Carbonates.

The most remarkable of these salts, is the *double carbonate of lime and magnesia*, $MgO.CO^2+CaO.CO^2$. 93.44, forming the minerals called *dolomite*, *bitter spar*, and *pearl spar*.

The rock called *magnesian limestone*, is an impure variety of dolomite.

Barito-calcite is a *double carbonate of baryta and lime*, $CaO.CO^2+BaO.CO^2$. 149.44.

Carbonate of soda fused with the carbonate of baryta, strontia or lime, in the ratio of their equiv., yields crystalline, definite compounds; in the same manner also, sulphate of soda heated with the above carbonates, yields double salts which are very similar.

SECT. 3. ORDER. 2.

Hydro-salts.

This order includes those salts the acid or base of which contains hydrogen. The salts formerly called *muriates* or *hydrochlorates* of metallic oxides, are now generally described as chlorides of those metals, and also the salts of *hydriodic* and other hydracids. The only salts which are included in this order, are formed by the hydracids with *ammonia* and *phosphuretted hydrogen.*

Hydrochlorate of ammonia, H^3N+HCL. 53.57. This is the *sal-ammonia* of commerce, and was formerly imported from Egypt, where it was prepared from the soot of camel's dung by sublimation; but it is now formed by several processes. The most usual is to decompose the *sulphate of ammonia** by the chloride of sodium or magnesium.

It occurs *native*, in masses and in crystals, in the vicinity of volcanoes. It may be produced directly by introducing liquid ammonia into one retort, (see fig. 44. p. 104.) and HCL into the other, and apply heat. As the two gases pass into the receiver, a white cloud appears, which is hydrochlorate of ammonia in fine powder.

Properties. This salt has a pungent, saline taste, and is insoluble in water and in alcohol; it sublimes at a temperature below that of ignition, without fusion or decomposition.

Uses. Used in the arts for a variety of purposes, in tinning copper to prevent oxidation, and by dyers.

When dissolved in nitric acid it forms the *aqua regia*, which is employed for dissolving gold instead of nitro-hydrochloric acid.

Hydriodate of ammonia, $H^3N.HI$. 144.45.
Hydrobromate of ammonia, $H^3N.HBr$. 96.55.
Hydrofluate of ammonia, $H^3N.HI$. 36.83.

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* This sulphate is obtained by digesting with gypsum the impure carbonate of ammonia, procured from the destructive distillation of bones and other animal substances, so as to form an insoluble carbonate of lime, and a soluble sulphate of ammonia.

Hydrosulphate of ammonia, H^3N+HS. 34.25, is formed by heating a mixture of one part of sulphur, two of sal-ammoniac, and two of unslaked lime. It is used as a re-agent and for this purpose it is formed by saturating a solution of ammonia with hydrosulphuric acid.

Hydrocyanate of ammonia, H^3N+HC^2N. 44.54.

Hydro-sulpho-cyanate of ammonia, $H^3N+HCyS^2$. 76.74.

Tri-fluoborate of ammonia, $3H^3N+BF^3$. 118.39.

Difluoborate of ammonia, $2H^3N+BF^3$. 101.24.

Fluoborate of ammonia, H^3N+BF^3. 84.9.

Fluocilicate of ammonia, H^3N+SiF. 43.33.

Carbosulphate of ammonia, H^3N+CS^2. 55.47.

Salts of phosphuretted hydrogen.

Phosphuretted hydrogen, resembles ammonia in composition and in some of its properties; it is a feeble alkaline base, and combines with some of the hydracids.

SECT. 4. ORDER 3.

Sulphur salts.

The *sulphur-salts* are *double sulphurets*, just as the oxy-salts are *double oxides*.

The *sulphur-salts* with two metals are so constituted, that if the sulphur in each were re-placed by an equivalent quantity of oxygen, it would form an oxy-salt.

The close analogy between the two orders of salts appears also from the fact, that hydrosulphuric and hydro-sulpho-cyanic acids unite both with ammonia and sulphur bases.

The principal *sulphur bases* are the proto-sulphurets of potassium, sodium, lithium, barium, strontium, calcium, magnesium and the hydrosulphate of ammonia; and the *sulphur acids* are the sulphurets of arsenic, antimony, tungsten, molybdenum, tellurium, tin and gold, together with hydrosulphuric acid, bisulphuret of carbon and sulphuret of selenium.

The sulphur salts are divided into families which contain the same sulphur acid; the generic name of each family is formed from the sulphur acid terminated with *sulphuret;* thus the salts, which contain per-sulphuret of arsenic or hydrosulphuric acid as the sulphur acid, are termed *arsenio-sulphurets* and *hydrosulphurets,* and a salt composed of those sulphur acids, with sulphuret of potassium, is termed *arsenio-sulphuret,* and *hydrosulphuret* of sulphuret of potassium, or simply *hydrosulphuret of potassium.*

1. *Hydrosulphurets.*

The salts of this family have hydrosulphuric acid for their electro-negative ingredient; most of them are soluble in water, decomposed by exposure to the air and by acids.

Hydrosulphuret of potassium, $KS+HS$. 72.35.

The anhydrous salt may be obtained by heating to low redness, anhydrous carbonate of potassa in a tubulated retort, through which a current of hydrosulphuric acid is transmitted.

Hydrosulphuret of sodium, $NaS+HS$. 56.5.

Hydrosulphuret of lithium, $LS+HS$. 43.2.

Hydrosulphuret of barium, $BaS+HS$. 101.9, is formed by the action of hydrosulphuric acid on a solution of baryta, excluded from the air. It crystallizes in four-sided prisms, and is very soluble.

Hydrosulphuret of strontia, $SrS+HS$. eq. 77.
" *of calcium,* $CaS+HS$. eq. 53.7.
" *of magnesia,* $MgS+HS$. eq. 45.9.

2. *Hydro-sulpho-cyanurets.*

The acid of these salts is the hydro-sulpho-cyanuric acid.

Hydro-sulpho-cyanuret of potassium, $KS+HCyS^2$. 114.84, is a white, crystalline solid, soluble in water and in alcohol.

Hydro-sulpho-cyanuret of hydrosulphate of ammonia, $(H^3N+HS)+HCyS^2$. 93.84.

3. *Carbo-sulphurets.*

The acid of this family is the bisulphuret of carbon.

Carbo-sulphuret of potassium, $KS+CS^2$. 93.57, is prepared by agitating bisulphuret of carbon with a strong alcoholic solution of proto-sulphuret of potassium. The liquid, when set at rest, separates into three layers, the lowest of which is the carbo-sulphuret of potassium. On evaporation, a deliquescent, yellow, crystalline salt is deposited, sparingly soluble in alcohol.

The carbo-sulphuret of sodium, $NaS+CS^2$. 77.72, and the *carbo-sulphuret of lithium*, $LS+CS^2$. 64.42, are similar to the preceding.

Carbo-sulphuret of the hydrosulphate of ammonia, $H^3N.HS+CS^2$. 72.57, is a very volatile salt, and must be kept in bottles tightly corked. Exposed to the air, it absorbs water and becomes red.*

4. *Arsenio-sulphurets.*

Each of the three sulphurets of arsenic, is capable of acting as a sulphur acid; giving rise to three distinct families of sulphur salts, *arsenio-proto-sulphurets*, *arsenio-sesqui-sulphurets, and arsenio-persulphurets.* The persulphuret of arsenic, is the most powerful of these acids. The arsenio-persulphurets of the alkalies and alkaline earths, are very soluble in water, have a lemon-yellow color when anhydrous, but colorless when combined with water of crystallization, or in solution; but those of the second class of metals, are generally insoluble.

5. *Molybdo-sulphurets.*

The acid in this family is the *tersulphuret of molybdenum.* The most remarkable of these salts is *molybdo-sulphuret of potassium*, $KS+MoS^3$. 151.25, which is formed by decomposing a solution of molybdate of potassa with hydro-sulphuric acid; on evaporation, beautiful crystals with 4 and 8 sides are deposited. Berzelius describes this compound as the most beautiful which chemistry can produce. The crystals by transmitted light, are ruby-red, and their surfaces while moist, and also the solution which yields them, shine like the wings of certain insects, with a metallic lustre, of a rich green tint.

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* *The carbo-sulphuret of barium*, $BaS+CS^2$. 123.12; *the carbo-sulphuret of strontium*, $SrS+CS^2$. 98.22; and *the carbo-sulphuret of calcium*, $CaS+CS^2$. 74.92, may be obtained by acting on bisulphuret of carbon with a solution of the proto-sulphurets of these metals. The solutions are orange or brown, and the crystals, when dry, are of a citron-yellow color. *Carbo-sulphuret of magnesium*, $MgS+CS^2$. 67.12.

6. *Antimonio-sulphurets.*

The acid of this family is the sesqui-sulphuret of antimony, and the only salt examined is the *antimonio-sulphuret of potassium*, which may be formed by mixing two parts of carbonate of potassa, four of sesqui-sulphuret of antimony, and one of sulphur, and fusing the mixture.

7. *Tungsto-sulphurets.*

The best known of this family is potassium. When a solution of tungstate of potassa is decomposed by hydro-sulphuric acid, and the solution evaporates anhydrous, quadrilateral, flat prisms are deposited of a pale-red color, which is the tungsto-sulphuret of potassium. This salt unites with tungstate of potassa as a double salt.

Sect. 5. Order 4.

Haloid Salts.

This order includes substances composed like the preceding salts of bi-elementary compounds, one or both of which, are analogous to sea-salt in composition. The *haloid acids* belong generally to the electro-negative, and the *haloid bases* to the electro-positive metals.

The following, are the principal groups, or families.

1. *Hydrargo-chlorides.* The haloid acid is the bichloride of mercury; they are obtained by mixing their ingredients in the ratio of combination, and setting aside the solution to crystallize.
2. *Auro-chlorides.* The acid in this family is the ter-chloride of gold; they are prepared like the preceding; most of them have an orange, or a yellow color.
3. *Platino-chlorides.* The haloid acids in this family, are the *proto-chloride* and *bichlorode* of platinum.
4. *Palladio-chlorides*, are salts in which the chlorides of palladium act as haloid acids, combining with many of the metallic chlorides.

5. *Rhodio-chlorides*, are formed by the action of sesqui-chloride of rhodium on the chlorides of potassium and sodium.

6. *The chlorides of irridium* and *osmium*, are the haloid acids of the *irridio-chlorides*, and the *osmio-chlorides.*

7. *Oxy-chlorides.* This family embraces a large number of compounds in which a metallic oxide is united with a chloride generally of the same metal, but often of other metals. These salts are commonly termed *submuriates*, on the supposition that they consist of hydro-chloric acid, combined with two or more equiv. of an oxide.

Oxy-chlorides of iron. When the crystallized proto-chloride of iron is strongly heated in close vessels, a deep green oxy-chloride, in scaly crystals is formed.

Oxy-chloride of copper, constitutes the paint called *Brunswick-green*, and is prepared by exposing metallic copper to hydro-chloric acid. This is the compound formed by the action of sea-water on the copper of vessels.

Oxy-chloride of lead, may be formed by adding pure ammonia to a hot solution of chloride of lead; another oxy-chloride, the pigment called *patent yellow*, is prepared by the action of moist sea-salt on litharge.

Chlorides with ammonia. The perchlorides of tin and some other metals absorb ammonia at common temperatures, and most of the other chlorides absorb it when gently heated; but most of these compounds lose their ammonia, on exposure to the air, and nearly all, by heat.

Chlorides with Phosphuretted Hydrogen.

These are very similar to those with ammonia.

Double Iodides.

These compounds have not yet been closely studied, but the iodides probably form with each other an extensive family of salts.

The most important are the

Platino-biniodide of potassium, prepared by digesting an excess of biniodide of platinum, in a concentrated solution of iodide of potassium, and the *platino-biniodide of hydrogen*, which is prepared by acting on biniodide of platinum with a cold, dilute solution of hydriodic acid.

Oxy-iodides. The best known of this family are those formed by the oxide and iodide of lead.

The *double bromides* have not yet been studied.

Double Fluorides.

There are several extensive families of these salts, in which the fluorides of boron, silicon, titanium, and other electro-negative metals are the acids, and the fluorides of the electro-positive metals are the bases.

Double Cyanurets and Ferro-cyanurets.

The double cyanurets constitute a large and important family of salts, of which the principal are the ferro-cyanurets, ferro-sesqui-cyanurets, zinco-cyanurets, cobalto-cyanurets, nicco-cyanurets, and cupro-cyanurets, in which the proto-cyanuret of iron, sesqui-cyanuret of iron, cyanuret of zinc, cobalt, nickel, and copper are the electro-negative cyanurets. (See Turner's Elements, p. 487.)

CHAPTER VI.

NATURAL SUBSTANCES.

ORGANIC CHEMISTRY.

Organic chemistry treats of those substances which are of animal or vegetable origin, and which are therefore called organic. These substances differ from inorganic substances, in being composed of the same elements, oxygen, carbon and hydrogen, often with the addition of nitrogen, which is most abundant in fungous plants, and animal substances. On the other hand, inorganic compounds are composed of very different elements; a few other constituents, as iron, silica, potassa, sulphur, phosphorus, etc., are sometimes detected in small quantity in organic substances, but can rarely be regarded as essential constituents. These compounds differ chiefly in the proportions of their constituents; hence many of them are easily convertible into each other.

A second characteristic of organic substances is the facility with which they may be decomposed, and especially in being without exception, decomposed by a red heat, and often by a lower temperature; if heated in the open air, they are converted chiefly into water, and carbonic acid.

With a few exceptions, organic substances cannot be formed artificially by the direct union of their elements; they are obtained only as already existing in organic bodies, or by the conversion of one into another, as of sugar into alcohol.

Many organic acids and alkalies combine with inorganic alkalies or acids, and form compounds, which although not entirely of animal or vegetable origin, are usually described in connection with their organic constituents.

VEGETABLE CHEMISTRY.

Most vegetable substances consist of hydrogen and carbon, usually with oxygen; in fungous plants, and in some others, nitrogen is also present.

Proximate principles. All compounds, which exist in plants ready formed without artificial processes, as gum, sugar, starch, etc., are called *proximate principles;* the processes by which they are separated, constitute proximate analysis.

Ultimate analysis consists in the reduction of organic compounds into their elements. This was formerly done by *destructive distillation;* the substance was put into a close vessel and decomposed by a high temperature; the products were collected and examined. The process is now generally conducted by means of the oxide of copper, which easily parts with its oxygen to the carbon and hydrogen of the substance, forming carbonic acid with the former, and water with the latter. These new compounds are collected, and from their weight may be known the weight of the carbon and of the hydrogen. The loss of oxygen in the oxide of copper is also noted, and compared with the quantity in the carbonic acid and water. The excess of the latter over the former, is the amount derived from the substance under examination, and if there be no such excess, it is inferred that there was none in the substance.

SECT. 1. VEGETABLE ACIDS.

Vegetable acids are, for the most part, less liable to spontaneous decomposition than other organic substances, although none of them can exist at the temperature of a red heat; they all contain carbon and oxygen, and most of them hydrogen also; generally, they have more oxygen than would be sufficient to form water by combination with the hydrogen; but a few have these elements in the same ratio as in water, while in benzoic acid the hydrogen is in excess.

Oxalic acid, C^2O^3. 36, T. $2CO+O$. 36.24, L. was discovered by Scheele in 1776, and is found in several plants, among which is common sorrel, the sour taste of which is caused by the presence of oxalic acid; it is obtained also by the action of nitric acid on sugar. Many other organic substances, as starch, gum, most of the other vegetable acids also, wool, silk, etc., are converted into oxalic acid by the action of nitric acid; it contains more oxygen than any other organic substance.

Properties. Oxalic acid is sold in small slender crystals, and much resembles *Epsom salts*, for which it is sometimes mistaken with fatal consequences. But although a powerful poison, it may be tasted without danger, when its strong acidity will easily distinguish it; if taken by accident, powdered chalk in water or magnesia should be administered.

Oxalates of potassa. There are three of these compounds, one of which, the *binoxalate*, $HO.C^2O^3$, $KO.C^2O^2+2Aq$. 155.63, is often sold under the name of *essential salt of lemons*, for removing the stains of iron-rust from linen; a solution of oxalic acid will answer the same purpose.

Oxalate of lime, $CaO.C^2O^3+2Aq.=82.74$, exists in several species of lichen, and when recently precipitated, is a snow-white flaculent powder.

Ascetic acid, $C^4H^3O^3$. 51.48. This acid exists in the sap of many plants, and is generated in large quantities, in the destructive distillation of vegetable substances and in the acetous fermentation; it is the acid of common vinegar. *Pyroligneous* acid consists of acetic acid mixed with tar and a volatile oil, and is made by the distillation of wood. The concentraied acid is very strong and volatile, with a refreshing odor; its vapor is inflammable. Numerous salts are formed by this acid.

Acetate of lead, 1 eq. acid, 1 protox-lead, 3 water. This substance commonly known under the name of *sugar of lead*, is prepared by dissolving either the carbonate of lead (white lead,) or litharge, in distilled vinegar. Like most of the compounds of lead, it is highly poisonous.

Acetates of copper. Of these there are three or four. *Verdigris* is a variable mixture of them, and is prepared in France by covering copper with the refuse of grapes, after the juice has been extracted. In England a better article is prepared by covering copper plates with cloth soaked in pyroligneous acid.

Acetate of alumina is extensively employed by calico printers as a mordant for fixing colors *Acetate of iron* is also used for the same purpose; *acetate of ammonia* has long been used in medicine.

Malic acid, $C^4H^2O^4$. 60. This acid is contained in grapes, currants, gooseberries, oranges, apples, and in most of the acidulous fruits. It is also obtained by the action of nitric acid on ⅓ of its weight of sugar; it forms salts with metallic oxides called malates.

Citric acid, $C^4H^2O^4$. 60. This acid is also found in many acidulous fruits, especially in limes and lemons, from which it is usually obtained. It has an agreeable flavor, and is an excellent substitute for lemons; it is used in the preparation of lemon syrup, in which, however, tartaric acid is largely employed, being much less expensive, but of very inferior flavor. Citric and malic acids are isomeric.

Tartaric acid, $C^4H^2O^5$. 66.24. This acid also exists in acidulous fruits, usually in combination with lime or potassa. Tartaric acid is used with the bicarbonate of soda for an effervescing drink; it forms numerous salts, many of which are double.

Bitartrate of potassa. In an impure form, this is known by the name of *crude-tartar*, and is found incrusted on the sides of wine casks, colored by the wine; when purified, it is white, and is known by the name of *cream of tartar.* It is used for the preparation of tartaric acid, and as a medicine.

Tartrate of antimony and potassa. This compound is sold under the name of *tartar emetic*, and is prepared by boiling sesqui-oxide of antimony with cream of tartar. It is neutralized by vegetable astringents, as tea, or Peruvian bark, which may therefore be used as an antidote, in case of taking a too powerful dose.

Tannic acid, or *Tannin*, $C^{18}H^8O^{12}$. 212. This substance exists in gall-nuts, (the excrescences of several species of the oak,) in the bark of most trees, in tea, and in most vegetable astringents, and is the cause of their astringency. With gelatin, or glue, it forms an insoluble compound, which is the basis of leather. Hence leather is prepared by soaking skins in water, which contains ground bark, the tannic acid of which, is taken in solution by the water. When exposed to the oxygen of the air, it is gradually converted into gallic acid.

Gallic acid, $C^7H^3O^5$. 85. This acid also exists in gall-nuts and in the bark of trees, but is more abundantly obtained by the oxidation of the tannic acid of gall-nuts. Common *ink* owes its color to the compounds of tannic and gallic acids with the sesqui-oxide of iron, and may be extemporaneously prepared by adding to an infusion of gall-nuts, a solution of copperas, which has been exposed to the air.

Some of the most important of the remaining vegetable acids are the following:

Mellitic acid, C^4O^3. 24.48+24=48.48, is contained in the rare substance called *honey-stone.*

Croconic acid, C^5O^4. 30.6+32=62.6.

Lactic acid, $C^6H^5O^5$. 36.72+5+40=81.72, so called, from being first noticed in sour milk, and was discovered by Scheele in 1780.

Kinic acid, $C^{15}H^{10}O^{10}$. 91.8+10+80=181.8, exists in cinchona bark in combination with lime, quinia and cinchonia.

Pyro-citric acid, $C^{10}H^2O^3$. 61.2+2+24=87.2.

Racemic acid, $C^4H^2O^5$. 24.48+2+40=66.48, is associated with tartaric acid in the juice of the grape.

Benzoic acid, $C^{14}H^5O^3$. 85.68+5+24=114.68, exists in gum benzoin from which it is commonly extracted, in the balsams of Peru, and in several other vegetable substances, in the urine of the cow and other herbaceous animals.

Meconic acid, $C^7H^2O^7$. 42.84+2+56=100.84, is found in the poppy, in combination with morphia.

Metameconic acid, $C^{12}H^4O^{10}$. 73.44+4+80=157.44, is obtained from the meconic by boiling its aqueous solution.

Pyro-gallic acid, $C^6H^3O^3$. 36.72+3+24=63.72, is obtained by heating gallic acid to 419°.

Meta-gallic acid, $C^{12}H^3O^3$. 73.44+3+24=100.44, is formed by heating gallic acid to 480°.

Ellagic acid, $C^7H^2O^4$. 42.84+2+32=76.84, is very similar to the preceding.

Succinic acid, $C^4H^2O^3$. 24.48+2+24=50.48, exists in amber and is obtained by the aid of heat.

Mucic acid, $C^6H^5O^8$. 36.72+5+64=105.72.

Camphoric acid, $C^{20}H^{16}O^5$. 122.4+16+40=178.4, is obtained from camphor by nitric acid.

Valerianic acid, $C^{10}H^{9}O^{3}$. $61.2+9+24=94.2$, exists in the root *valerian* and is obtained by distillation.

Rocellic acid, $C^{16}H^{16}O^{4}$. $97.92+16+32=145.92$.

Moroxylic acid is found in combination with lime on the bark of the white mulberry.

Oily acids, so called because they are obtained from oils or fat, and enter into the composition of soaps.

Stearic acid, $C^{70}H^{6}O^{5}$. 527, is obtained from soap, and is a white, tasteless, inodorous substance, insoluble in water, and burning like wax. Its salts are termed *Stearates*.

Mangaric acid, $C^{70}H^{70}O^{9}$. 562, is distinguished from the preceding by fusing at 140°. When distilled with lime, a white substance is obtained, called *margarone*.

Oleic acid, $C^{70}H^{63}O^{7}$. 538, is obtained from the soap made from linseed oil and potassa. It burns like the fixed oils and forms salts, or soaps called *oleates*.

The *azulmic acid*, $C^{8}H^{4}N^{4}O^{4}$, the *indigotic*, $C^{23}H7\frac{1}{2}N1\frac{1}{2}O^{15}$, which is obtained by boiling indigo in rather dilute nitric acid, and the *carbazotic* acids, $C^{15}N^{3}O^{15}$. 252, also is obtained from indigo containing nitrogen.

The *pectic*, $C^{11}H^{7}O^{10}$. 153; *crenic* 108, and *apocrenic acids* have not been fully examined.

There are also a numerous class of compound acids. For a complete description of the vegetable acids, the student is referred to Thompson's Chem., Organ. Bodies.

Cyanogen and its compounds. A numerous class of bodies are formed by the combination of cyanogen with other substances which exist in the vegetable and mineral kingdoms: for a description of which, see Webster's Chem., and also Thompson's Chem., Organ. Bodies.

SECT. 2. VEGETABLE ALKALIES.

The existence of vegetable alkalies was not known until the present century, and very little attention was given to them until 1816. They are eighteen or twenty in number; their constitution is remarkable, as they each contain one equiv. of nitrogen in each equiv. of the alkali. The equivalents of oxygen vary from one to six, of hydrogen from twelve to twenty-two, and of carbon from twenty to thirty-four; all, which have been analyzed, consists of these four elements. In vegetable bodies they usually exist in combination with acids, forming salts.

The method of preparation is nearly the same for all of these alkalies; the substance which contains one of them, is steeped in a large quantity of water which dissolves the salt that contains it; the solution is boiled for a short time with lime or magnesia, and the vegetable alkali is set free in an insoluble state, and may be collected on a filter with the lime; if then boiled in alcohol with powdered charcoal, it is dissolved by the former, and purified by the latter; then by filtering while hot, it is separated from the charcoal and the lime with which it was mixed; it is deposited from the alcohol on cooling, by evaporation.

Morphia, $C^{34}H^{18}N^{1}O^{6}=284$. This alkali is the narcotic principle of opium, in which it is combined with sulphuric and meconic acids, and is associated with several other vegetable alkalies, and with gummy, resinous and coloring matters; opium contains about nine and a half per cent. of morphia; when pure, it is very insoluble in water and consequently but little poisonous; but when in the state of a salt as in opium, it is a very powerful poison; one half a grain in solution will produce alarming effects on the animal system; when opium has been administered as a poison, the presence of its morphia may be detected by a process too elaborate to be inserted here. A skilful chemist will detect a single grain of morphia in 700 grains of water; some of the salts of morphia are useful as medicines; of which the *hydrochlorate* and *acetate* are the principal.

Narcotina, $C^{40}H^{20}NO^{12}=370.24$, was discovered by Desrone in 1803, and is obtained from opium; it is a white substance, and may be taken into the human stomach without sensible effects, but it is speedily fatal to dogs.

Cinchonia, $C^{20}H^{12}NO1\frac{1}{2}=158$, *and quinia*, $C^{20}H^{12}NO^{2}=162$. These two alkalies were detected by Pelletier and Caventou in 1820, in Peruvian bark, and impart to it its value as a medicine. *Cinchonia* is found in the pale bark; *quinia* with a little cinchonia in the yellow bark, and both in the red bark. Cinchonia is insoluble in cold water, and nearly so in hot water; in boiling alcohol it is freely dissolved, and the solution has an intensely bitter taste; some of its salts are soluble in water.

Quinia or quinine is also almost insoluble in water, but with alcohol forms an intensely bitter solution.

Quinia forms several salts, one of which, the *sulphate*, is manufactured in large quantity for medical purposes, and is commonly sold by the name of *quinine*. It is soluble in alcohol, or slightly in pure water, and freely if the water is slightly acidulated by sulphuric acid; the solution, although containing but a minute portion of quinia, is intensely bitter.

On account of its high value, sulphate of quinia is often adulterated with gum, starch, sugar, magnesia and various other substances; gum and starch are insoluble in alcohol, and may be detected by dissolving the suspected quinia in boiling alcohol. Sugar may be detected by adding pearlash to the solution in water, when the quinia will be thrown down and the sweet taste may be perceived; magnesia will be left after burning a portion of the adulterated article.

Strychnia, $C^{30}H^{16}NO^{3}=237.75$, was discovered in 1818, by Pelletier and Caventou. This remarkable alkali is found in the *nux vomica* and in the *upas tree*. It is freely soluble in alcohol, and but slightly so in water; although nearly insoluble in the latter, the minute portion which is taken up, communicates to the water the most intense bitterness; a single grain of strychnia will render eight gallons of water bitter. It is one of the most virulent poisons yet discovered; half a grain in the throat of a rabbit occasioned death in five minutes. Its action is always accompanied by symptoms of *locked-jaw.*

Emetia. This alkali constitutes 16 per cent. of *ipecacuanha,* and appears to be the sole cause of its emetic properties.

Sanguinaria is a peculiar alkali, discovered by Mr. Dana in the *blood root,* (Sanguinaria Canadensis.) Its salts have a red color.

Nicotina is the peculiar principle of tobacco; it is a virulent poison.

SECT. 3. NEUTRAL SUBSTANCES.

Sugar, $C^{12}H^{10}O^{10}=162.24$. Sugar is found in most ripe fruits, but more abundantly in the sap of the maple tree, in the sugar-beet, and in the sugar-cane; from the latter it is obtained by evaporating the juice by a moderate ebullition, until the syrup is sufficiently thick to crystallize on cooling. During this operation, lime water is added to neutralize the acid present, and to remove impurities which rise with the lime in a scum to the surface; it is next drawn off into shallow coolers, in which it becomes a soft solid. Lastly, it is put into barrels with holes in the bottom, through which the *molasses* gradually runs out, leaving raw or brown sugar. Raw sugar is purified by boiling it with the white of eggs or bullock's blood, and lime water; it is then received into conical vessels, and in cooling assumes the form of *loaf sugar.*

When two pieces of loaf sugar are rubbed together in the dark, phosphorescence is observed; it is obtained in large crystals by fixing threads in a syrup, which evaporates gradually in a warm room; in this state it is called *rock-candy.* Sugar does not deliquesce when exposed to the air, except when impure, as raw sugar. It is soluble in an equal weight of cold water, and is much more soluble in warm water; it is soluble in four times its weight of boiling alcohol, from which solution fine crystals are obtained. The vegetable acids diminish the tendency of sugar to crystallize, as in molasses.

By the action of sulphuric acid, starch, and common wood may be converted into sugar.

Sugar of grapes, $C^{12}H^{12}O^{12}$, contains rather less carbon than common sugar, and is rather less sweet.

Honey consists of two kinds of sugar, one of which when separated crystallizes, and the other is uncrystallizable. Besides sugar, it contains gum and probably an acid; when diluted with water, honey undergoes the vinous fermentation. Common sugar requires the addition of yeast for this change.

Manna is the concrete juice of several species of ash, and owes its sweetness, not to sugar, but to a distinct principle called *mannite*.

Liquorice owes its sweetness to a saccharine principle which is quite distinct from sugar.

Starch. Starch exists abundantly in the vegetable kingdom. It is the principal constituent of most kinds of grain, potatoes, and other farinaceous substances. It is obtained from potatoes by washing them in cold water, when the gluten, which is the other principal constituent, remains in the hand, and the starch is mechanically diffused through the water. The water is then allowed to stand, and the starch subsides, while the saccharine and mucilaginous matters remain in solution. When made from the dough of wheat flour, the water containing the soluble and insoluble parts of the flour is allowed to ferment; acetic acid is thus formed, which dissolves the gluten, and facilitates the separation of the starch.

Starch is easily converted into sugar. In the germination of seeds, and in the malting of barley or other grain, this change takes place. If starch is boiled for a considerable time in water, which contains $\frac{1}{12}$ its weight of sulphuric acid, it is converted into a kind of sugar like that obtained from grapes.

Arrow root, prepared from the root of a plant, is a very pure starch. *Sago*, prepared from the pith of an East India palm-tree, and *tapioca* and *cassava* from the root of a plant, are essentially the same.

Gluten. Gluten exists with starch in most kinds of grain, which are chiefly composed of two principles. It is obtained from wheat flour by washing out the starch and soluble matter, and boiling the remainder in alcohol. On adding water and distilling of the spirit, it is deposited. It is without taste, very tenacious, elastic and insoluble in water. When kept warm and moist, it ferments. The tenacity of common paste is owing to the gluten which it contains. The *rising of bread* is caused by the fermentation of gluten, the tenacity of which retains the bubbles of carbonic acid gas formed in fermentation. Gluten has been resolved into four distinct principles, viz.: vegetable albumen, emulsin, mucin and glutin; these substances are obtained by the action of alcohol upon the gluten of wheat.

Gum. Under this name are included all those vegetable principles, which form, when dissolved in water, an adhesive, viscid liquid, called *mucilage*, and which yield an acid called mucic acid, when boiled with four times their weight of nitric acid. Gum is insoluble in ether and alcohol, and is precipitated by them from its aqueous solution, as an opaque, white substance; but with acids and alkalies it is more soluble than in pure water.

Gum Arabic is the most common variety of gum; it is obtained from several species of acacia or minerosa in Africa and Arabia. *Gum Senegal* differs in no important respect from gum Arabic. The gum of the peach, plum and cherry-tree, although identical in composition with gum Arabic, differ in being insoluble in cold water; after being boiled, however, it assumes the characters of that gum. *Gum tragacanth* differs from gum Arabic in containing a large portion of bassoric, starch and water; it is tougher than common gum, which is quite brittle. Gum tragacanth is therefore a very useful ingredient in paste. The jelly of fruits is distinct from gum in some properties, but is nearly allied.

Lignin. Lignin or the woody fibre constitutes the fibrous structure of plants, and is the most abundant principle in them. The common kinds of wood contain about 96 per cent. of lignin. It is insoluble in alcohol or water. With strong alkalies or acids it is changed. With sulphuric acid it is changed into gum, and on boiling is further changed into a sugar, like sugar of grapes. Straw, bark and linen, in the same way may be converted into sugar.

SECT. 4. OILS.

These substances are divided into *fixed* and *volatile oils.* The former are not much affected by a heat which does not decompose them, while the latter rapidly pass away in vapor. The greasy stain of the former on paper or any other surface is permanent, that of the latter soon disappears.

Fixed oils. The vegetable fixed oils are usually obtained from seeds, as the almond, linseed, and poppy seed. *Olive oil,* however, is extracted from the pulp around the stone. The density of these oils is less than water, varying from .9 to .96. They are solid at a low temperature. They burn with a clear, white light. By exposure to the air they become rancid, and at length viscid. In this change oxygen is absorbed, and the oil itself probably undergoes some change, although it has been supposed, that rancidity was caused by the acidification of some mucilage present. By heating the oil in open vessels, it acquires the property of drying rapidly, in which process much oxygen is absorbed, and carbonic acid and hydrogen given off. *Drying oils* are used for paint, and when mixed with lamp-black constitute printers' ink. Drying oils sometimes absorb oxygen so rapidly as to set fire to combustibles. Spontaneous combustion often occurs where cotton has been moistened with them.

By means of mucilage or sugar, the fixed oils may be permanently suspended in water. Such a mixture is called an *emulsion*. With ammonia they form a soapy liquid called *volatile liniment*, which is a direct compound of oil and the alkali. The fixed alkalies have a similar action in the cold, but when heated, *soap* is generated. A further notice of soaps will be found under animal chemistry.

The fixed oils consist of two proximate principles, one of which called *margarine*, is solid at common temperatures, while the other is fluid, and is called *oleine*.[*]

These oils consist of carbon, hydrogen and oxygen.

The principal fixed oils are the following:

Olive oil, which is expressed from the pericarpum of the fruit of the common olive (olea Europea). By the action of hyponitrous acid, the solid substance called *elaidin* is formed. It contains an acid called *elaidic*, which combines with alkalies and forms soaps; it is used as an article of luxury.

Croton oil is obtained from the *croton tiglium* of the East Indies, and possesses powerful purgative properties.

Palm oil has the consistency of lard, and is used in the manufacture of yellow soap.

Cocoa-nut oil is a white, hard substance, used as a substitute for tallow.[†]

Volatile, or Essential Oils.

The flavor of aromatic plants is owing to the presence of volatile oils, which are obtained by distillation. Water must be added to the plants to keep them from burning. Some however are obtained by expressing the rinds of certain fruits, such as the *orange*, *lemon*, *bergamot*. Although usually of an agreeable odor, those oils have an unpleasant acrid taste; but when diluted, some of them have an agreeable taste. They are but slightly soluble in water, and are freely dissolved in alcohol. Such solutions are commonly sold under the name of *essences*. Like the fixed oils, they burn with a clear, white light. They have the property of dissolving sulphur, and the solution is called *balsam of sulphur*.

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[*] From ελαιον, oil.

[†] The various kinds of wax, such as *beeswax*, *myrtle wax* and *cow-tree wax*, are regarded as similar in composition with the fixed oils, and are classed by some chemists with them.

A few of these oils, as the oil of turpentine, of lemons, and of copaiva, contain only carbon and hydrogen; others contain oxygen also. A few contain one or more additional elements, as sulphur and nitrogen.

The principal volatile oils are oil of turpentine, lemons, anise, juniper, chamomile, carraway, lavender, peppermint, rosemary, camphor, cinnamon, cloves, sassafras, mustard and bitter almonds.

Common spirits of turpentine consists of resin dissolved in the oil of turpentine, which last may be obtained by distillation.

Camphor is a volatile oil, solid at common temperatures. On account of its toughness it is pulverized with difficulty, unless a few drops of alcohol be added. It is insoluble in water, but is freely soluble in alcohol. *Artificial camphor* may be formed by passing a current of hydrochloric acid gas through oil of turpentine or oil of lemons. Camphor is very offensive to insects, which are prevented from devouring cabinets of natural history, collections of birds, insects, etc. by placing pieces of camphor in the cases.

Resins. Resins are the concrete juices of plants, solid, brittle and without taste; they are good non-conductors of electricity, and by friction become negatively electrified; they are easily melted, and burn with a yellow flame and dense smoke. They are soluble in alcohol, ether and the essential oils, but are quite insoluble in water.

The different kinds of resin are numerous. *Common resin* is procured by heating turpentine; the volatile oil is expelled, and resin remains.

Turpentine is the juice of several species of pine trees. Other resins are *copal, lac, mastick*, and *dragon's blood.*

Copal is the most important, and is used for varnish. *Indian* ink is a solution of *borax, lac*, and *lamp-black.*

The uses of resin are various. Dissolved in oil or alcohol, and diluted with spirits of turpentine, they form various kinds of varnish. *Sealing-wax* is made of lac, turpentine, and common resin. It is colored red with cinnabar or red-lead, or black with lamp-black.

The soot, which is procured from the combustion of resinous wood, turpentine, or resin, is *lamp-black.* When turpentine is extracted by heat, it is partially changed, and becomes *tar.* When tar is thickened by boiling, it becomes *pitch.*

Amber is a fossil substance, consisting of a peculiar bituminous matter and resin. It often contains insects.

Balsams are the juices of some kinds of trees. Some are solid, others are liquid. They are composed of resin and benzoic acid.

Gum-resins are the hardened juices of certain plants, consisting of resin, gum, and volatile oil. Their proper solvent therefore, is a mixture of alcohol and water, or common spirits. They are numerous and many of them are valuable medicines; among them are *aloes, assafœtida, galbanum, gamboge, myrrh*, and *guiacum.*

Caoutchouc, or India-rubber, is obtained from four species of trees, two of which grow in South America, and two in the East Indies. It is usually black, but when not darkened by smoke is of a whitish-color. It burns with a bright flame, is insoluble in water or alcohol. It is soluble in ether, the essential oils, etc. If a bag of it be soaked in ether, it will become soft and gelatinous before dissolving, and in that state may be blown out into a very large and thin bag. The most useful solvent of caoutchouc is a dark volatile liquid, obtained by the careful distillation of caoutchouc itself; about four-fifths of the solid pass over in this liquid form.

Wax. Wax is found in the pollen or dust of flowers, on some leaves as a kind of varnish, and especially on the berries of the wax-plant, *myrica cerifera.* As bees deposit wax, when fed only on sugar, beeswax is an animal product. Wax is insoluble in water, and is sparingly dissolved by alcohol and ether. It is composed of two principles, *cerin* and *myricin.*

Creosote. This substance exists in tar, and in pyroligneous acid. It is a colorless, oily liquid, with an odor like smoked meat. It has a burning taste, followed by sweetness. Its most remarkable property is that of preserving meat. The antiseptic properties of smoke, and crude pyroligneous acid, appear to be owing to this substance. It is soluble in 80 parts of water, and freely in alcohol. Insects and fish are killed by the aqueous solution. It is said to be useful as a cure for toothache, ulcers, etc.

SECT. 5. SPIRITUOUS, AND ETHEREAL SUBSTANCES.

Alcohol, C^4H^5O+HO. 46. This substance is the product only of fermentation, and is never found ready formed in any vegetable substance. It is obtained by the distillation of ardent spirits, of which it constitutes 50 per cent. After a second distillation it still contains some water, most of which may be removed by carbonate of potassa added in a dry state. Common alcohol has a specific gravity of about .86, but when freed from water, of .82. The purest alcohol boils at a temperature of 176° Far., is highly inflammable, burning with a very pale blue, but hot flame. No smoke is produced in its combustion, and hence it is of great utility for lamps in a laboratory, various kinds of apparatus being thus conveniently heated, and not soiled with smoke. Although exposed to a temperature of –176° Far., alcohol has never been frozen.

Alcohol combines with water in every proportion. With an equal quantity of water, it constitutes spirit of the *first proof.* The density of this is about .92. The density will be in proportion to the weakness of the spirit. Proof spirit is very useful in cabinets of natural history, for the preservation of specimens of fishes, reptiles, etc. Its effects upon the animal system as a poison are well known. It has the power of passing into the circulation undigested, and irritates all the organs with which it comes in contact. The stronger wines contain 18 to 25 per cent. and the weaker, from 12 to 17 per cent. In wines it appears to have less intoxicating power than in ardent spirits, which may be owing to its chemical combination with mucilaginous and saccharine matters.

As a solvent, alcohol is useful. Many vegetable principles, not soluble in water, are freely so in alcohol. Both mineral and vegetable alkalies are soluble, but it does not dissolve the earths, or other metallic oxides.

Ethers. Most of the stronger acids, when heated with alcohol, yield a very volatile, inflammable liquid, called ether. Different kinds are formed from different acids.

Sulphuric ether, C^4H^5O, is the most common. It is prepared by boiling equal weights of alcohol and sulphuric acid; the vapor of ether passes over, and is condensed in a vessel surrounded by ice-cold water.

The specific gravity of pure ether is .7, as commonly sold .74. It boils at the temperature of blood heat. In a vacuum it boils at –40° Far. It congeals at –46° Far. It is slightly soluble in water, but combines with alcohol in all proportions.

Hydrochloric ether, C^4H^5Cl, is formed by the action of hydrochloric acid on alcohol. It burns with an emerald-green flame without smoke.

Nitrous ether, $C^4H^5O + NO^3$, is produced by the action of equal quantities of nitric acid and alcohol, and resembles sulphuric ether, but is more volatile.

Oxalic ether, $C^4H^5O + C^2O^3$, is formed by mixing 1 part of alcohol, 1 binoxolate of potassa, and 2 of SO^3.

Œnanthic ether, $C^4H^5O + C^{14}H^{13}O^2$, gives to wines their peculiar odor, and is obtained in the distillation of wine as an oily liquid, which is a mixture of œnanthic ether with excess of œnanthic acid. The ether is separated by distillation. It produces intoxication when inspired.

Pyroxylic spirit, C^2H^3O+HO. 32, is a kind of ether formed by heating wood, and comes over with the aqueous liquid. It has an alcoholic and aromatic odor, and is employed by hatmakers for the purpose of dissolving shell-lac, and mastic to stiffen, and render hats water-proof.*

SECT. 6. COLORING MATTERS.

The most common colors in the vegetable kingdom are green, yellow, blue and red. The greater part of the infinite diversity of colors consists of different shades or mixtures of these. The coloring matter of plants is usually diffused through other proximate principles. All vegetable colors are destroyed by chlorine, and usually changed by acids or alkalies.

Lakes are insoluble compounds of coloring matter with alumina, or oxide of iron or of tin.

Process. Dissolve alum in a colored solution, and on adding an alkali, as potassa, alumina will be precipitated, and at the moment of separation from the alum, will combine with the coloring matter.

In dyeing, some colors have a sufficient affinity for the fibre of the cloth to remain fast on a mere immersion of it. In many cases, however, this is not sufficient, and the color would be removed by washing. A third substance is introduced, which, having an affinity both for the coloring matter and the cloth, fixes the former permanently to the latter; this third substance is called the *mordant* or *basis*; those which are in common use are alumina in alum, oxide of iron in copperas, and chloride of tin, which is converted into the oxide. All the colors of dyed stuffs are produced from the four, blue, red, yellow and black.

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* For a complete description of ethers, see Thompson, *Org. Bodies.*

Blue dyes. Indigo is the most important of these, and is obtained from several species of a genus of plants which are cultivated in America and Asia. The plants are fermented and beaten in water, at the bottom of which the indigo subsides. Common indigo contains in addition to its peculiar blue, a red and a brown coloring matter, with some gluten. Pure indigo sublimes at 550° Far. and condenses in acicular crystals. It is insoluble in water, and but slightly soluble in boiling alcohol; it is soluble in sulphuric acid. If indigo be put into a tub with three times its weight of green vitriol, and an equal quantity of slaked lime with water, the protoxide of iron will be precipitated by the lime from the green vitriol, and the indigo will be de-oxidized by it and become yellow. Dyers dip their cotton cloth into it in this condition, and by exposure to air the cloth becomes permanently blue.

Red dyes. The most common substances for red dyes are cochineal, lac, archil, madder, Brazil wood and logwood.

Cochineal is obtained from an insect which feeds upon the leaves of several species of the *cactus*, and which is supposed to derive this coloring matter from its food. It is very soluble in water, and is fixed on cloth by means of alumina or oxide of tin. Its natural color is crimson, but when bitartrate of potassa is added to the solution, it yields a rich, scarlet dye. The beautiful pigment called *carmine*, is a lake made of cochineal and alumina or oxide of tin.—T. *Archil* is obtained from a lichen which grows in the Canary Islands. *Litmus*, which consists of red coloring matter and alkali, is prepared from it. *Madder* is the root of the *rubia tendorum*, and employed for dyeing the *Turkey red.*

Yellow dyes. The principal are quercitron bark, turmeric, saffron and fustic.

Black dyes. These are prepared from the same ingredients as writing ink. The addition of log-wood and acetate of copper gives a *blue black.*

SECT. 7. FERMENTATION.

Many vegetable substances when exposed to warmth and moisture undergo spontaneous changes, and the process is called fermentation. It is most commonly observed in substances containing gluten, starch, gum or sugar. In different stages of the process, sugar, alcohol, and acetic acid are formed, and finally, there is a total dissolution of the substance. These stages of the process are called the *saccharine*, *vinous*, *acetous and putrefactive* fermentations.

Saccharine fermentation. Starch only is subject to this kind of fermentation. The quantity of sugar produced equals in weight half of the starch employed. The ripening of fruits has been regarded as a kind of saccharine fermentation, in which the acid of the green fruit is converted into sugar; this change is caused by heat, not by the vitality of the plant.

Vinous fermentation. When sugar with water, and yeast or some other ferment is exposed to a warm temperature, the sugar is converted into carbonic acid gas and alcohol, in nearly equal weights of each. As starch is convertible into sugar by fermentation, if the process be continued under the above conditions, it will be converted into alcohol and carbonic acid. All vegetable bodies contain some substances which act as a ferment, and therefore, by the addition of moisture and regulation of the temperature, various kinds of grain containing starch, and of ripe fruits containing sugar, will undergo the vinous fermentation. Thus cider is formed from apples, and beer from grain. To obtain ardent spirits, the fermented liquor is heated, and the alcohol passes over by distillation.

In the fermentation of bread, the saccharine matter of the flour is resolved into alcohol and carbonic acid gas. The latter causes the dough to rise, and the former is entirely expelled by the heat of baking. A company in London was formed for collecting the spirit emitted by the baking of bread; if the fermentation of dough be continued, it undergoes the change next described, and becomes sour.

Acetous fermentation. Any liquid which has undergone the vinous fermentation, or pure alcohol with water and yeast, exposed to the air in a warm place, undergoes a change, in which oxygen is taken from the air, and carbonic acid thrown off. In place of alcohol, acetic acid is found in the liquor. Thus cider becomes sour by age, if exposed to the air, and at length is converted into vinegar. In France wine is converted into vinegar, and in England, an infusion of malt.

Acetic acid is often formed in the spontaneous decomposition of vegetable substances without sugar. In these cases, the process is quite different from the acetous fermentation properly so called.

Putrefactive fermentation. Many vegetable principles, as the acids, oils, resins and alcohol, are not subject to putrefaction; those which contain oxygen and hydrogen in the proportion to form water, and especially those in which nitrogen exists, are subject to this change; moisture, and a moderately warm temperature are essential to the process, which is also promoted by air; water serves to loosen the particles of the substance, and enables them to act freely upon each other.

The products of vegetable putrefaction, are carbonic acid gas, and light carburetted hydrogen. In stagnant waters, which contain decaying plants, these gases often rise in bubbles, especially if the bottom be stirred. Usually, light carburetted hydrogen, is the most abundant gaseous product. In plants, which contain nitrogen, ammonia is generated; water is the principal liquid product, and vegetable mould, consisting of charcoal, a little oxygen and hydrogen, the solid product.

SECT. 4. GERMINATION.

Germination refers to the process by which a new plant originates from the seed. The seed consists of two parts. The *germ*, which is endowed with the vital principle, and the *cotyledons*, or *seed lobes*, which furnish nourishment to the plant before it can derive it from the earth. The *germ* is composed of the *radicle*, or that part which descends into the ground, and forms the root, and the *plumula*, which rises into the air and forms the stem of the plant.

The three conditions, necessary to the germination of the plant, are moisture, a certain temperature, and oxygen gas. Dry seeds will not germinate, or if moist, germination will not take place at 32°, nor at the temperature of boiling water, which deprives the germ of its vitality. The most favorable temperature is from 60° to 80°, varying with the nature of the plant. Air is also necessary to germination, for if seeds are buried deep, excluded from the air, they will never pass through this process.

In the malting of barley, the process of germination may be accurately studied. The malting is done by exposing the grain to moisture, warmth and air, until it begins to germinate, and then drying it in a kiln, where the temperature ranges from 100° to 160°, or more. The chemical changes which take place in this process, are the following. The *hordein*, an insoluble substance, is converted into starch, gum and sugar, which are soluble, and very nutritive substances, easily absorbed by the radicle of the plant; at the same time, oxygen gas is consumed, and carbonic acid gas is given off.

Growth of plants. There are many points of resemblance between the growth of plants and of animals; and also many points in which they differ. The chemical changes which the sap undergoes, by what is called the *respiration of plants*, is probably very analogous to what takes place in the blood of animals. With this difference, however, that animals consume oxygen, and throw off carbonic acid, while vegetables absorb carbonic acid and yield oxygen gas, provided in the latter case, they are exposed to sunshine. In the night the reverse often takes place; light seems necessary to the coloring of plants, and to their health and perfection.

Food of plants. Plants derive their food for the most part from the earth. The soil generally consists of siliceous earth, clay, lime, and sometimes magnesia, mixed with the remains of animal and vegetable substances. The water passes through it, and dissolves the salts contained in it, and absorbs the gaseous, extractive and other matters, which the process of decomposing animal and vegetablo remains produce. It is then absorbed by the roots of the plant, and is conveyed to the leaves where it is fitted to nourish the plant.

There are some plants, however, which do not derive their nutrition from this source, as they are found to vegetate in distilled water, and to grow for some time when merely suspended in the air. This is accounted for on the supposition that carbonic acid is the proper food for plants. This substance is obtained from the atmosphere, absorbed by the leaves of the plant, and appropriated to its nourishment. When plants are burned, their ashes contain various salts which must have been derived from the earth.

The peculiar vegetable substances which are formed from sap, appear to be under the control of the vital principle, over which the ordinary agents of chemical changes have but little power.

CHAPTER VII.

ANIMAL CHEMISTRY.

With the exception of the oils, animal substances usually contain a large portion of nitrogen, and have a strong tendency to putrefaction. Their proximate principles are much less numerous than those of vegetables. In addition to carbon, hydrogen, oxygen and nitrogen, sulphur, phosphorus, iron, earthy and saline matters are usually present in animal bodies.

SECT. 1. PROXIMATE PRINCIPLES NEITHER ACID, NOR OLEAGINOUS.

Fibrin. This principle is the basis of the muscles, and is found abundantly in the blood. It is a white, insipid solid when pure, and easily putrefies. When subjected to the action of nitric acid, it throws off a large quantity of nitrogen, and with acetic acid forms a jelly.

Albumen. Albumen exists in a solid state in the skin, glands and vessels, and in a liquid state in the serum of blood, the fluid of dropsy, and the white of eggs. The latter substance consists almost solely of it. When liquid, it is coagulated by heat, as in the boiling of an egg, or by alcohol, and the stronger acids. Corrosive sublimate is a very delicate test, producing a milkiness in water, which contains $\frac{1}{2000}$ albumen.

Gelatin. This substance is abundant in the solid parts of animals, in the skin, cartilages, membranes and bones. It is easily soluble in boiling water, and forms a bulky jelly on cooling. One part in 100 of water, will render the whole solid when cool. The jelly is a hydrate of gelatine, and if the water be expelled by a gentle heat, it may be preserved for any length of time. This is *glue*, which is prepared from the ears, skins and hoofs of animals. *Isinglass* is the purest variety, prepared from the sounds of fish.

Osmazome exists in the muscular fibres. It is very insoluble, and is supposed to give to broth its peculiar flavor.

SECT. 2. ANIMAL ACIDS.

Many acids are found in animals, which are found also in the animal and vegetable kingdoms; such are the sulphuric, hydrochloric, phosphoric and acetic acids. Those, which are peculiar to animals, are very few, and are derived chiefly from urine, or from oils and fats; of the latter, are stearic, oleic and margaric acids. Formic acid, is a remarkable acid found in ants, and is ejected by them when they are irritated.

SECT. 3. ANIMAL OILS AND FATS.

These substances are very similar to the vegetable oils, and either may be used in the manufacture of soap, or for giving light.

Train oil is obtained from the blubber of the right whale, and is much inferior for lights, to *spermaceti.*

Spermaceti oil is obtained from the blubber of the sperm whale, and from a large cavity in the head, from which twelve or fifteen barrels of liquid oil are sometimes dipped out. This substance is strained through stout bags, which are subjected to a strong pressure. The solid which remains is *spermaceti*, of which candles are manufactured, and the liquid is the spermaceti oil. As the oil is more liquid in hot weather, *summer-strained oil* contains more spermaceti, and a given quantity will therefore produce more light, and burn less freely than *winter-strained oil;* the latter is usually preferred as giving a clearer light, and being less affected by cold, but it is much less economical.

Hog's lard and *suet* are well known substances differing much in respect to their point of fusion.

Animal oils and fats are not proximate principles, but consist chiefly of *stearine* and *margarine*, which are solid at common temperatures, and *oleine*, which is liquid.

Soaps. When any of the animal or vegetable oils or fats are boiled with a solution of potassa or soda, the former are converted into margaric, oleic, or stearic acids, and another principle called glycerine. The acids combine with the alkali, and form *soap.* The compounds, which they form are soluble in pure water, but in solutions containing salts of lime, oxide of lead, and many other metallic compounds, they combine in preference with these oxides, and form insoluble compounds. Hence hard water, containing salts of lime, curdles soap.

Ambergris, found floating on the ocean, is supposed to be a concretion formed in the stomach of the sperm whale.

SECT. 4. COMPLEX ANIMAL SUBSTANCES.

Blood.

Blood consists of a liquid, through which are diffused red globular particles. The liquid portion consists of water, holding in solution fibrin, with albumen, and saline and oily matters. When set at rest it coagulates, forming a jelly. The red globules are also compound, containing fibrin and the coloring matter. In mammiferous animals these globules are spherical, but in birds, reptiles and fishes, they are ellipsoidal.

When blood is set at rest, it does not separate into the two parts above-mentioned, but into a red coagulum called the *clot* and the *serum*, which is a yellowish liquid.

The saline substances contained in the blood, are carbonates, phosphates, and sulphates of potassa and soda. It contains also chloride of sodium, (common salt,) chloride of potassium and sesqui-oxide of iron. More than ¾ of the blood are water, the coloring matter is in the ratio of 125 parts in 1000, and albumen about 67 in 1000. The proportions vary somewhat even in the the same person at different times.

The following table by M. Le Canu represents the composition of the blood as derived from two careful analyses.

Water,	780.145	785.590
Fibrin,	2.100	3.565
Coloring matter,	133.000	1196.26
Albumen,	65.090	69.415
Crystalline-fatty matter,	2.43	4.300
Oily matter,	1.310	2.270
Extractive matter soluble in water and alcohol,	.790	1.920
Albumen combined with soda,	1.265	2.010
Chloride of sodium, " of potassium, Carbonates, Phosphates, Sulphates, of soda and potassa,	8.370	7.304
Carbonates of lime and magnesia, Phosphates of lime, magnesia and iron, Peroxide of iron,	2.100	1.414
Loss,	2.400	2.586
	1000.000	1000.000

The changes which are effected on the blood by respiration, are due to the oxygen of the atmosphere. The dark blood of the veins enters the lungs, and being there exposed to the action of the air through a thin membrane, absorbs oxygen, throws off, or forms carbonic acid gas, and passes into the arteries with a bright red color. A large quantity of carbonic acid is emitted by the lungs, and hence the necessity of a free circulation of air in small, or crowded rooms.

Animal heat. There is a striking analogy between the process of combustion and respiration. In both cases, oxygen is consumed, and carbonic acid produced. This fact led Dr. Black to infer that the heat generated in the animal system, was derived from the change which takes place in the lungs. That the development of animal heat is dependent upon respiration, is a matter of easy demonstration ; but how the effect takes place, has not been satisfactorily explained. In those animals which consume a small quantity of oxygen, the temperature of their bodies varies with the surrounding medium, and are called *cold-blooded*, but in those that consume a larger quantity of oxygen, the temperature is nearly uniform, whatever be the temperature of the medium. They are hence called *warm-blooded*. The temperature of the same animal varies often, according as the respiration is sluggish, or rapid.

To account for animal heat, Dr. Crawford proposed the first consistent theory, which is founded on the supposition that the blood, when purified by the oxygen of the air, has its capacity increased for caloric ; and hence the heat produced in the lungs by the consumption of the oxygen, enters into an insensible state in the arterial blood. As this blood circulates through the system and enters the veins, it loses its capacity, and gives out its caloric. But Dr. Davy denies that there is any difference between the capacity of venous, and arterial blood. If, however, we suppose that the oxygen does not combine with the carbon in the lungs, but in the course of circulation, there would be heat developed in all parts of the system; and this view would account for the facts, irrespective of the different capacities of the two kinds of blood.

The influence of the vital principle, doubtless has much to do, both in the development and preservation of animal heat. The nerves have been supposed also to possess a specific power of generating heat, but whatever be the cause, it is evident that the *arterialization* of the blood does not account for all the heat of the animal system, from the fact that a healthy animal imparts more heat to surrounding bodies, than could be produced from this source alone.

Saliva. This liquid contains only seven parts of solid matter in a thousand. It contains chloride of potassium, sulphate, phosphate, acetate and carbonate of potassa, with some other salts. It forms a soft, pulpy mass with the food in mastication, preparing it for more easy digestion.

Gastric juice. This fluid taken from an empty stomach has a saline taste, and is neutral. But when any substance enters the stomach, acid is secreted. Both hydrochloric and acetic acids are formed. All nutritious substances are dissolved by this juice, and converted into a pulpy mass called *chyle.* It does not act on living substances, or the stomach itself would be dissolved, as sometimes is the fact after death. Its solvent power is due to the acids, which are greatly aided by the temperature of the stomach. By taking magnesia the acids are neutralized, and the digestive power suspended for the time.

Bile. The bile is a yellow, or greenish nauseous liquid, of which $\frac{7}{8}$ are water, and the remainder a peculiar bitter principle, called *picromal,* with resin, and several salts. The bile stimulates the intestinal canal, and assists in converting the chyme into *chyle.*

Chyle. This is a white fluid resembling milk. It contains about 90 per cent. of water; of the other constituents, albumen is most abundant.

Milk. This liquid is well known to consist of cream, curd and whey. 100 parts of cream, of specific gravity 1.0244, contain only 4.5 parts of butter; of the remainder 92 are whey, and 3.5 curd. The coagulation in sour milk is produced by the generation of acetic acid, which, in common with acids generally, separates the curd from the whey. The same effect is caused by rennet prepared from a calf's stomach, which is impregnated with the gastric juice, and therefore contains acid. Milk is of course curdled when taken into the stomach.

Lymph is a peculiar, limpid, transparent liquid, which moistens the cellular membrane, and collects abundantly in some dropsical affections. It consists chiefly of water, with hydrochlorate of soda and albumen.

The *humors of the eye* contain more than 80 per cent. of water; the other ingredients are albumen, muriate and acetate of soda, pure soda, and an animal matter like curd, which gives it a milky appearance.

The *tears* contain pure soda, chloride of sodium, and phosphate of soda, with water, and an animal matter analogous to albumen.

Mucus is a fluid secreted by the mucus surfaces, as the nose.

Pus is a liquid matter secreted by an inflamed, and ulcerated surface. Its characteristic ingredient resembles albumen.

Sweat is the vapor which constantly passes off from the skin, and consists mostly of water, mixed with a little muriate of soda, and free acetic acid.

Urine differs from most animal fluids in serving no ulterior purpose in the animal economy. It is an *excretion* consisting of substances which would prove injurious to life and health, The urine is separated by the kidneys from the blood, and consists of a great variety of substances, such as water, and urea, which are the principal, uric acid, lactic acid, lactate of ammonia, mucus, sulphates of potassa and of soda, phosphates of soda and of ammonia, muriates of soda and of ammonia, earthy matters with a trace of fluate of lime, and siliceous earth.

Eggs. The shell of an egg is about $\frac{1}{10}$, the white $\frac{6}{10}$, and the yolk $\frac{3}{10}$ of the whole. The shell consists chiefly of carbonate of lime; and the white, of albumen with a little sulphur. The yolk contains phosphorus, which supplies phosphoric acid for forming the bones of the chicken.

Bones. Bones contain about $\frac{1}{3}$ of animal matter, $\frac{1}{2}$ of phosphate of lime, $\frac{1}{10}$ of carbonate of lime, with a little fluoride of calcium, and some other salts. *Teeth* have the same composition, but the enamel contains 78 per cent. of phosphate of lime. The *shells* of crustaceous animals, as *lobsters* and *crabs*, consist of carbonate and phosphate of lime with animal matter; but the shells of molluscous animals, or *true shells*, as of the oyster, snail, etc., consist almost entirely of carbonate of lime, and animal matter.

Horn differs from bone in containing only a trace of earth. The composition of the *nails*, *hoofs*, and *cuticle* of animals is similar to horn.

Tendons are composed almost wholly of gelatin.

The true *skin* has nearly the same composition, *membranes* and *ligaments* contain in addition some substance which is insoluble in water, and is similar to coagulated albumen.

Hair contains a peculiar animal substance, insoluble in water at 212°, but soluble in a solution of potassa. It also contains an oil, which gives the peculiar color of the hair; *sulphur* upon which the *nitrate of oxide of silver* acts in staining it, together with silica, iron, manganese and carbonate and phosphate of lime.

Wool and *feathers* are similar in composition to hair.

Silk is covered with a peculiar varnish, which amounts to about 23 per cent.

Muscle. The *lean flesh* of animals consists essentially of fibrin, with numerous other ingredients, such as albumen, gelatin, a peculiar extractive matter called *osmazome*, fat and salts.

CHAPTER VIII.

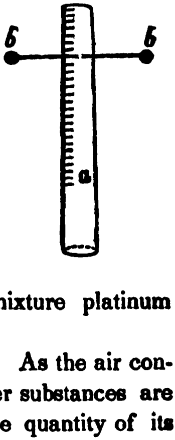
ANALYTICAL CHEMISTRY.

It is the object of analytic chemistry to point out the method of separating compound bodies into their simple elements. As the subject is extensive, a few things only will be inserted here, in order to give the student an idea of the nature of the process.

SECT. 1. ANALYSIS OF MIXED GASES.

1. *Gaseous mixtures containing oxygen.* The best process by which oxygen gas may be withdrawn from gaseous mixtures, is by means of hydrogen gas. In case of the air, a given portion is taken, and rather more hydrogen added than is sufficient to combine with the oxygen. The mixture is then introduced into a strong glass tube, or eudiometer, (fig. 84.) over water or mercury, and exploded by the electric spark. The total diminution in volume, divided by three, will give the quantity of oxygen present. Instead of exploding the gases, they may be made to combine slowly by introducing into the mixture platinum sponge.

Fig. 84.



2. *Gaseous mixtures containing nitrogen.* As the air contains only oxygen and nitrogen, when other substances are withdrawn, if its oxygen is determined, the quantity of its nitrogen may be easily known. The only mode of ascertaining the quantity of nitrogen in any mixture, is to withdraw the other gases from it.

3. *Gaseous mixtures containing carbonic acid.* When carbonic is the only acid gas present, as is the case with air, and organic compounds, the process consists merely in absorbing this gas by lime water, or a solution of caustic potassa.

4. *Gaseous mixtures containing hydrogen and other in-*

flammable bodies. The quantity of hydrogen when mixed with nitrogen, oxygen, or atmospheric air, is ascertained by adding a portion of oxygen, and exploding the mixture. The quantity of other inflammable bodies, such as carbonic oxide, light carburetted hydrogen, or olefiant gas mixed with nitrogen, is determined by adding a sufficient quantity of oxygen, and detonating the mixture. The diminution of volume indicates the quantity of hydrogen contained in the mixture, and by withdrawing the carbonic acid, the quantity of carbon may be known.

SECT. 2. ANALYSIS OF MINERALS.

In order to analyze any mineral compound, the first object is to bring the body into a state of solution. This is effected generally by water or acids, but in cases where the substance is not dissolved by these, it is made into a paste, with three or four times its weight of potassa, soda, baryta, or their carbonates, and subjected to a strong heat in a platinum or silver crucible. By this means, the alkali combines with one or more of the constituents of the mineral, and then it is in a state to be acted upon by acids.

The analysis of carbonate of lime (marble), is effected by simply heating it until all the carbonic acid is driven off. The loss will indicate the quantity of acid.

To separate siliceous, and aluminous earths from lime-stone, dissolve it in hydrochloric acid, and these earths will remain insoluble. To separate carbonate of magnesia from lime-stone, the process is more difficult.

Earthy sulphates. The sulphate of lime is easily analyzed by boiling it for 15 or 20 minutes in a solution of twice its weight of carbonate of soda. The carbonate of lime and sulphate of soda are formed by double decomposition. The sulphate of soda is then decomposed by chloride of barium, and the carbonate of lime analyzed in the usual way.*

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* For other sulphates, see Turner, p. 241.

The compounds of silica, alumina, and *iron,* are decomposed by an alkaline carbonate at a red heat. For further details, the student is referred to Turner's Chemistry.

SECT. 3. ANALYSIS OF MINERAL WATERS.

The purest water is obtained by distillation. ***Rain-water***, or that from fresh fallen snow, is next in purity.

Well and *spring water* contain some salts, which are derived from the soil through which the rain-water passes, hence the purity of water will depend upon the nature of the soils. If it is filtered through primitive strata, such as granite, it will contain few salts, but if through secondary soils, such as limestone and gypsum, it becomes impregnated with various other substances and is *mineralized.* Lime renders it *hard.*

The different kinds of mineral-water, are *acidulous, alkaline, chalybeate, sulphuretted, saline,* and *silicious springs.*

In *acidulous springs* of which those of Saratoga, and Seltzer are examples; the acidity is due to the carbonic acid with which their waters are impregnated. They frequently contain protoxide of iron, carbonates of lime, magnesia, and other saline compounds. The *carbonic acid* is easily expelled by heat, and may be collected over mercury.

Alkaline springs are very rare. They generally contain free, or carbonated alkali.

Chalybeate springs. These waters are characterized by a styptic, inky taste, and by striking a black color with infusion of gall-nuts. The iron is either combined with hydrochloric and sulphuric acids, or exists in the form of proto-carbonate held in solution by free carbonic acid. On exposure to the air, the protoxide is oxidized, and the hydrated peroxide subsides as an ochreous deposit, which is commonly found in the vicinity of chalybeate springs.—T.

Sulphuretted springs are characterized by their odor, and by the brown precipitate which a salt of lead or silver occasions. This is owing to the hydro-sulphuric acid gas which they contain. The quantity of gas is ascertained by boiling the water, which expels it.

Saline springs owe their properties to saline compounds, such as sulphates and carbonates of lime, magnesia and soda, and the chlorides of calcium, magnesium, and sodium.

In the analysis of saline springs, the first object is to ascertian the nature of the ingredients. Hydrochloric acid is detected by nitrate of oxide of silver, sulphuric acid by chloride of barium, and if an alkaline carbonate be present, the precipitates will contain a carbonate of oxide of silver, or of baryta. Lime and magnesia may be detected, the former by oxalate of ammonia, and the latter by phosphate of ammonia. Potassa is known by the action of chloride of platinum. To detect soda, the water should be evaporated to dryness, the deliquescent salts removed by alcohol, and the matter insoluble in that menstruum taken up by a small quantity of water, and allowed to crystallize by spontaneous evaporation. The salt of soda may then be recognized by the rich yellow color which it communicates to flame. If the presence of hydriodic acid be suspected, the solution is brought to dryness, the soluble parts dissolved in two or three drachms of a cold solution of starch and strong sulphuric acid slowly added.—T.

APPENDIX.

Electro-magnetism. In the description of the *Revolving Rectangle*, p. 87, fig. 34, the pole-changer is said to "consist of two pieces of copper or steel, with a small space called a *break*, between them." The pieces of metal are silver, or should be, and as the space between does not *break* the current but only sends it in a different direction, the term *break* does not apply to the instrument as thus constructed. A *break*, is generally a piece of metal which interrupts the current, as is shown in fig. 41, p. 92. It may consist of air, or any non-conducting substance so connected with a conductor, that when the wire conveying the current passes from the conductor to the non-conductor, the current may be broken. In the description of this instrument p. 88, it is stated that "when the sides of the rectangle arrive in the plane of the poles, they acquire sufficient force to pass by, etc." It might appear from this that the power ceased to act at that point, which is not the case; their tendency is to pass around the magnet, the force acting in the direction of a tangent to the circle in which the rectangle moves, continues to operate until the sides of the rectangle stand again at right-angles to the poles of the magnet, the point from which they commenced their revolution. The currents are then reversed and the revolution is continued. As the phenomena of *volta and magneto-electric induction* are produced only at the moment the battery current is arrested by the break, and that of *magneto-electric induction* only when the wire surrounding the armature is passing across the break-piece; it is necessary to assume these facts, in order that the theory stated on p. 94, may fully explain the phenomena.

Wollaston's Synoptic Scale of Chemical Equivalents.[*]— The scale consists of a moveable slider with a series of numbers upon it, from 10 to 320, on each side of which and on the fixed part of the scale, are set down the names of various chemical substances.

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[*] The paper, by its author, describing the scale is inserted in the *Philosophical Transactions* for 1814.

The scale is founded on the constancy of composition in chemical compounds; the equivalent power of the quantities that enter into combinations; and the properties of a logometric scale of numbers.

The numbers are so arranged, that at equal intervals they bear the same proportion to each other. The student will easily observe and understand this, by measuring a few distances upon the scale with a pair of compasses, or even a piece of paper. If his paper extend from 10 to 20, it will also extend from 20 to 40, or from 55 to 110, or from 160 to 320. Whatever number is at the upper edge of the paper will be doubled at the lower. If any other distance be taken, the same effect will be observed. If, for instance, the paper extends from 10 to 14, then any other two numbers found at its upper and lower edge will be in the same proportion as these two numbers 10 and 14. Thus make the upper number 100, and the lower number will be 140.

Now supposing that the paper were cut of such a width that, one of its edges being applied upon the scale to the number representing the equivalent of one body, the other should coincide with the number of the equivalent of a second body; then upon moving the paper, wherever it was placed over the numbers, those at its upper and lower edges would still represent the corresponding proportional quantities of the two bodies as accurately as at first, because the numbers at equal distances on the scale are proportional to each other. Thus suppose the upper edge were made to coincide with 40 and the lower with 78, then the upper edge might be called sulphuric acid, and the lower baryta; and this width once ascertained, the paper wherever applied upon the scale, would show at its lower edge the quantity of baryta necessary to combine with the quantity of sulphuric acid indicated by its upper edge.

It is evidently of no consequence whether the paper be moved up and down over the scale, or the line of numbers be moved higher and lower, to bring its different parts to the edges of the paper. And supposing the piece of paper just described to be pasted upon the side of the scale, then by moving the latter any of the numbers might be made to coincide with the upper or lower edge at pleasure, and consequently the quantity of sulphuric acid necessary to combine with any quantity of baryta, and vice versa, ascertained by mere adjustment and inspection of the scale. Or if, instead of referring to the separate piece of paper, marks were to be made on the side of the scale at 40 and 78, and named sulphuric acid and baryta, the same object would be attained, and the same method of inquiry rendered available.

Other substances are to be put down upon the scale exactly in the same manner. Thus the scale being adjusted until the number forty coincides with the sulphuric acid already marked, then sulphate of baryta is to be written at 118, and thus its place is ascertained; nitrate of baryta at 132; soda at 32; sulphate of soda at 72; and a similar process is to be adopted with every substance, the number of which has been ascertained by experiment. The instrument, which in this state merely represents the actual numbers supplied by experiment, will faithfully preserve the proportions thus set down, whatever the variation of the position of the slider may be. It is therefore competent to change all the numerical expressions to any degree required, the knowledge of one only being sufficient first by adjustment, and then by inspection to lead to the rest.

A few illustrations of the powers and uses of this scale will be sufficient to make the student perfect master of its nature and applications. Suppose that in analyzing a mineral water, the sulphates in a pint of it have been decomposed by the addition of muriate of baryta, and the resulting sulphate of baryta washed, dried and weighed; from its quantity may be deduced the exact quantity of sulphuric acid previously existing in the mineral water. Thus, if the sulphate of baryta amount to 43.4 grains, the slider is to be moved until that number is opposite to *sulphate of baryta*, and then at *sulphuric acid* will be found the quantity required, namely 14.7 grains. In the same manner the scale will give information of the quantity of any substance contained in a given weight of any of its compounds; these having previously been deduced from experiment, and accurately set down on the table in the manner just explained.

If it be desired to know how much of one substance must be used in an experiment to act upon the other, it is evident that the equivalent must be taken, and this may be learned from the scale. Suppose that a pound of sulphate of baryta has been mixed with charcoal, and well heated, to convert it into a sulphuret, and that by the addition of nitric acid it is to be converted into nitrate of baryta. The quantity of acid which will probably be required may be learned by bringing 100 to sulphate of baryta, and then by looking for the number opposite nitric acid; it will be found to be 46. But this represents the quantity of dry acid; casting the eye therefore lower down, upon liquid nitric acid of a specific gravity of 1.50, it will be found that 61 lbs. or a little more, is the equivalent for 100 lbs. and consequently that 61 hundreth parts, or somewhat above $\frac{6}{10}$ of a pound of such acid, will be sufficient for the pound of sulphate of baryta operated with.

If a certain weight of carbonate of baryta be required in that moist and finely divided state, in which it is obtained by precipitation, and in which it cannot be weighed, the accuracy of the quantity may be insured by taking the equivalent of dry muriate, or nitrate of baryta, precipitating it by an excess of carbonate of potassa, and then washing off the salts which remain in solution. Suppose 100 grains of the carbonate were required; by bringing that number to carbonate of baryta, it will be found that the quantity of dry muriate necessary will be 105.8 parts, and the quantity of nitrate 133.4; and if the quantity of carbonate of potassa necessary for this purpose be also required, it will be found opposite the name of that substance on the scale, to be a little less than 70 parts, so that 5 or 10 parts more will ensure a satisfactory excess.

The second paragraph of Wollaston's description of this scale may be transcribed, as a further illustration of the powers of the instrument. "If, for instance, the salt under examination be the common blue vitriol, or crystallized sulphate of copper, the first obvious questions are—(1) How much sulphuric acid does it contain? (2) How much oxide of copper? (3) How much water? He [the analytic chemist] may not be satisfied with these first steps in the analysis, but may desire to know further the quantities (4) of sulphur, (5) of copper, (6) of oxygen, (7) of hydrogen. As means of gaining this information, he naturally considers the quantity of various reagents that may be employed for discovering the quantity of sulphuric acid (8), how much baryta, (9) carbonate of baryta, or (10) nitrate of baryta, would be requisite for this purpose? (11) How much lead is to be used in the form of (12) nitrate of lead; and when the precipitate of (13) sulphate of baryta, or (14) sulphate of lead are obtained, it will be necessary that he should also know the proportion which either of them contains of dry sulphuric acid. He may also endeavor to ascertain the same point by means of (15) the quantity of pure potassa, or (16) of carbonate of potassa requisite for the precipitation of the copper. He might also use (17) zinc, or (18) iron for the same purpose, and he may wish to know the quantities of (19) sulphate of zinc, or (20) sulphate of iron, that will then remain in the solution."

All these questions and points are answered by moving the slider until the number expressing the quantity operated with, coincides with *sulphate of copper crystallized.* 5, *Water.* Let it for instance be 100; this being brought opposite crystallized sulphate of copper, the information relative to all the above points, except the sixth and seventh, is supplied by mere inspection. The sixth may be supplied by substracting (5) the quantity of copper from (2) the quantity of oxide of copper, or by halving the quantity at 2 oxygen, or taking the third of that at 3 oxygen. The seventh relates to the quantity of hydrogen in the 5 water present in the salt; this quantity of hydrogen does not come within the line of numbers, but may easily be obtained by doubling the quantity of water, or doubling the quantity of the salt used, which will then bring 10 hydrogen into the scale, and the half of this is to be taken as the quantity in 5 water, or in 100 grains of the salt. Putting therefore 200 to sulphate of copper, 10 hydrogen, is indicated as 17 parts nearly, when of course the half of this or 8.5 parts is the quantity in 100 grains of the crystallized salt of copper.

Whenever it thus happens that the number known or the number sought for is out of the scale, then some convenient multiplier of the numbers may be used. The most convenient method is to use the tens or the hundreds as units, or what is the same thing, to consider for the time that decimal points are inserted between the units and the tens, or between the tens and the hundreds of all the numbers on the scale. Thus if it were required to ascertain how much magnesia and sulphuric acid were contained in a pound of crystallized sulphate of magnesia, no 1 exists upon the scale, and of course no fractions or small parts of 1; but imagine decimal points between the tens and the hundreds, then 10 upon the scale becomes one-tenth, 22 twenty-two hundredths, 100 one, 220 two and two-tenths and so on. Bringing therefore 100 to crystallized sulphate of magnesia, it represents the 1 pound, and by inspection it will be found that it contains 16 hundredths of a pound of magnesia, and 32⅛ hundredths of a pound of sulphuric acid.

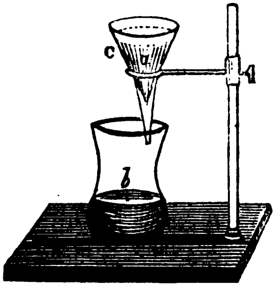
As another illustration; suppose that the quantity of magnesia in 50 lbs. of crystallized Epsom salt were required; upon bringing 50 opposite the name of the salt, the quantity of magnesia will be found smaller than any quantity expressed upon the scale: but all that is necessary to obtain the answer is, to double the quantity of the salt, and then to halve the quantity of magnesia indicated; in which way it will be found that the 50 lbs. contain about 8 lbs. of the oxide.

These *Synoptic scales* are generally constructed of paper or wood. It is almost impossible that they should be accurate, because of the extension and contraction of the paper, and the facility with which it yields to mechanical impressions, and may be stretched when in a moistened state. These scales should never be considered as accurate when they first come from the instrument-maker. They may be examined by a pair of compasses or a piece of paper, to ascertain how nearly, equal intervals on the scale of numbers, accord with equal proportions between the numbers at the extremities of those intervals and thus the degree of error in them, and the part where it exists to the greatest extent may be observed; but it will be useless to do so, with the view of finding one so accurate as to dispense with calculation in exact, analytical experiment.

Those scales, which are laid down directly upon wood, though not liable to the same sources of error as the paper scales, are still seldom, if ever, so accurate as to compete with calculation.—W.

Filtration. When a solution has been prepared for examination, it ought to be perfectly clear. If it appears muddy it must be subject to *filtration*, that is, it must be passed through a paper filter, by which means it is separated from solid matters which make it appear opaque. As this operation frequently occurs in chemical analysis and in various manipulations, it is important to understand the mode of performing it.

Fig. 83.



The filtering paper should contain no glazing or sizing, and after it is folded should be placed in a funnel *c* (fig. 84.), supported by a lamp-stand or a wood-stand made for the purpose, or it may be placed in the top of a tall jar, the liquid to be filtered is then put into it and a vessel placed beneath to contain the liquid as it slowly passes through the paper. By this process, the solid and liquid parts are separated and either may be examined in their separate state.*

Cementing. 1. When vapors of watery liquors, and such others as are not corrosive, are to be confined, it is sufficient to surround the joining of the receiver to the retort with slips of wet bladder, or of linen, or paper, covered with flour paste, or mucilage of gum-arabic.

2. Soft cement is made of yellow wax melted with half its weight of turpentine and a little Venetian red to give it color. It can be easily moulded by the fingers, and sticks well to dry substances.

3. For containing the vapors of acid, or highly corrosive substances, *fat lute* is made use of. This is formed by beating perfectly dry and finely sifted tobacco pipe clay, with painters' drying oil, in a mortar, to such a consistence that it may be moulded by the hand. To use it, it is rolled into cylinders of a convenient size, which are applied, by flattening them, to the joinings of the vessels, which must be quite dry, as the least moisture prevents the lute from adhering. The lute, when applied, is to be covered with slips of linen spread with the lime lute ; which slips are to be fastened with pack thread.

4. When penetrating and dissolving vapors are to be confined, the lute to be employed is of quick lime slacked in the air, and beaten into a liquid paste with white of eggs. This

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* For *chemical manipulation* and *blow-pipe analysis*, the student is referred to *Griffin's Chemical Recreations*.

must be applied on strips of linen ; it is very convenient, as it easily dries, and becomes firm. This lute is very useful for joining broken china ware.

5. For cementing stone ware to metals and wood, litharge and red lead mixed and worked up with spirit of turpentine, makes a good cement. It takes several days to give off the turpentine and become dry and hard.

6. Cement for fastening brass necks upon glass jars, etc. :—4 parts of rosin, 1 of wax, and 1 of finely powdered brick, melted and well mixed together. It is to be put on warm, but care is to be taken not to apply it so hot as to split the glass. It holds very hard.

7. Mix lintseed meal with water, and knead it into a stiff paste. It soon hardens and withstands the fumes of acids and ammonia. It is better if made with lime water, or thin glue. It is charred by a strong heat.

8. Thick gum water, with pipe clay and iron filings. Mix well. It becomes very hard and firm, and is fit to be used where it is required to hold good a considerable time.

9. Plaster of Paris, stirred up with milk, starch water, or thin glue. It hardens immediately, and is very good for securing tubes in flasks, when the corks do not fit well, and gases are to be prepared in them.

10. Dissolve melted India rubber in boiling lintseed oil, and afterwards thicken the latter with pipe clay till it forms a stiff mass. The thorough incorporation of the pipe clay demands a great deal of labor. This is a capital cement to be used when acids are to be prepared.

11. *Cement for fastening labels upon bottles.* Soften and subsequently boil glue in strong vinegar. During the boiling, thicken it with flour. This mixture can be preserved in a soft state without becoming mouldy. It should be put into a glass bottle, with a wide neck and a ground stopper. When it is to be used, it is taken out of the bottle on the point of a spatula, warmed over the lamp, if two thick for use, and then spread upon the paper.

12. *Universal Cement.* milk, press out th
whey, break the curd in sr it, and grind it i
coffee mill. Take ten our , one ounc
burnt quick lime, and tv camphor
whole intimately, and pr wide m
tles, closely corked. W used, r
little water, and apply it

13. ***Diamond Cement for Glass or Porcelain.*** Dissolve five or six pieces of gum mastic, as large as peas, in the smallest possible quantity of alcohol. Mix this liquid with two ounces of a strong solution of isinglass, (made by softening and dissolving isinglass in boiling brandy or rum to saturation), having previously incorporated the two ounces of isinglass solution with two or three small pieces of galbanum or gum ammoniac, by trituration. The mixture is to be preserved in a well closed bottle, and is to be gently heated by holding the bottle in hot water at the moment when you are going to use it.—*Griffin's Chem. Recreations.*

Elastic Tube Making. Take a piece of the sheet rubber, 1 or 1½ inches long, and a little more than three times as wide as you intend the tube to be. Take a glass rod rather smaller than the intended caoutchouc tube, fold a slip of paper round the glass rod, and over it the piece of caoutchouc, previously softened by warming before the fire. Fold the two edges together, and cut off the double projecting edges by a pair of scissors, so as to produce two parallel straight edges. Put the two clean surfaces thus produced face to face, being careful not to let the fingers or any thing else touch them. Press the two faces together by the thumb nails, and finally press the seam from end to end with the flat part of the thumb nail. The junction is then effected and the tube complete. But if the fingers or any dirt is allowed to touch the clean cut surfaces of the rubber, they cannot be made to unite by pressure. After you have withdrawn the glass rod and the slip of paper from the rubber tube, you are to smear its inner surface with flour or fine ashes. to prevent the subsequent sticking together of its sides, which is otherwise liable to take place.—*Ib.*

Specific Gravity of Essential and other Oils.

Oil of Anise-seed,	0.9958
“ “ Bergamot,	0.885
“ “ Cajeput,	0.948
“ “ Caraway.	0.975
“ “ Cassia,	1.071
“ “ Cinnamon,	1.035
“ “ Cloves,	1.061
“ “ Fennel,	0.997
“ “ Juniper,	0.911
“ “ Lavender,	0.898
“ “ Lemons,	0.8517
“ “ Nutmegs,	0.948
“ “ Peppermint,	0.899
“ “ Roses, (Ottar of Roses),	0.832
“ “ Rosemary,	0.85

Oils of Fermented Liqours.

Oil of Grain Spirits,	0.835
“ “ Potato Spirits,	0.821

Cutting Glass. Dissolve in spirits of turpentine as much camphor gum, as the liquid will hold in solution by the aid of moderate heat—a common file dipped into the solution and applied to glass, will cut it with nearly the same facility as iron.

TABLE.

The following are the results obtained by a commission appointed by the Parisian Academy of Sciences to examine the elastic force of vapor. They were obtained by experiment up to a pressure of 25 atmospheres, and at higher pressures by calculation.*

Elasticity of the vap. taking atmospheric press. as unity.	Temperature according to Far.	Elasticity of the vap. taking atmospheric press. as unity.	Temperature according to Far.
1	212°	13	380.66°
1½	233.96	14	386.94
2	250.52	15	392.86
2½	263.84	16	398.48
3	275.18	17	403.82
3½	285.08	18	408.92
4	293.72	19	413.78
4½	300.28	20	418.46
5	307.5	21	422.96
5½	314.24	22	427.28
6	320.36	23	431.42
6½	326.26	24	435.56
7	331.70	25	439.34
7½	336.86	30	457.16
8	341.78	35	472.73
9	350.78	40	486.59
10	358.88	45	491.14
11	366.85	50	510.60
12	374.00		

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* Brande's *Jour*. N. S. viii; 191.

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